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AN ANALYSIS OF THE CATCHES OF THE CHARTER BOAT, MELE MOKU

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INTRODUCTION

In recent years, the Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service (NMFS) has shown increased interest in research on marine recreational fishing in Hawaii. Unlike commercial fishing, where much information has been obtained by State and Federal agencies, there are practically no catch and operational data available for the marine recreational fishery in Hawaii. A few records are being kept of billfish tournaments such as the Hawaiian Billfish Tournament and the Hawaiian Invitational Billfish Tournament, but these are catches from individual tournaments only and do not include all of the troll fishery catch and effort. The Hawaii Fishing News publishes fish catch reports which include a large portion of the billfish catch, but do not encompass the total catch and effort made by charter boats. In the recreational fishery for bottom fish, catch and effort information is almost nonexistent. The NMFS is, therefore, looking for sources of fishing data which may help in monitoring the various recreational fisheries, and enable the recommendation of measures to ensure optimum utilization of the important species being caught. We hope to use such operational and catch information summarized in this report as part of monitoring the charter boat community in Hawaii.

The Mele Moku is a 13.1 m (43-ft) charter fishing boat based in Pearl Harbor and operated by the Hickam Air Force Base Morale, Welfare, and Recreational Division for use by personnel of the Department of Defense. It is managed by Lou Foster, the harbor master of the Hickam Air Force Base Small Boat Harbor and operated with nonappropriated funds. With the cooperation of Lou Foster and Captain Kenneth Brunst, we were able to extract operational and catch data from the Mele Moku's official logbooks. The captain also made his personal logs available to us.

Since this report includes the analysis of catch per unit effort, for uniformity the data used were only those obtained when the regular captain operated the vessel. Therefore, this report summarized the trolling catches and operational data of the Mele Moku only when operated by the regular or full-time captain from 1977 through 1982. The summaries of operational and catch data including all captains from April 1979 through 1982 are presented in the Appendixes.

OPERATIONS

During the 1977-82 period, the Mele Moku was normally operated on a schedule of a 6-day week, weather permitting and if the boat was chartered. Tuesdays were set aside for maintenance, but there were 7-day charters at times. Occasionally the vessel remained in port for prolonged periods for repairs or other reasons.

For a charter involving trolling, a flat fee of $180 was charged for a maximum of six people. These trips normally began at 0700 and ended at 1400. The captain operated the boat by himself, but on occasion took on a volunteer crewman when there were five or fewer people in the party. On rare occasions the boat was chartered for bottom fishing, and on such

occasions the fishing time was decided by the captain and those chartering the boat.

Area of Operation

The vessel operated mostly in the lee of Oahu in a triangular area bordered by Penguin Bank to the east, an area a few miles off Barbers Point to the southwest, and the entrance to Pearl Harbor. The trolling "legs" did not extend beyond 30 nmi in any direction starting from the entrance to Pearl Harbor.

Trolling Gear

Trolling was conducted with six lines while maintaining speeds averaging 8-9 knots. Lures of varying sizes were made from plastic heads with squid skirts. On occasion, two handlines were trolled with small feather jigs to catch smaller fishes.

RESULTS

Catch

Catch in number and weight by species and species group is presented in Table 1 for the 6-year period. Averaged over this period, billfishes contributed the greatest percentage by weight (55.1%), followed by tunas (29.2%) (Fig. 1). In numbers caught, tunas were the most numerous (62.3%), followed by "other" (15.3%). The "other" category includes small reef and bottom fish, which contributed little in terms of weight caught in spite of their relatively large numbers.

Blue marlin, Makaira nigricans, accounted for 85.4% by weight (15,717 kg; 34,656 lb) of the marlin catches. Yellowfin tuna, Thunnus albacares, followed the blue marlin with 5,985 kg (13,198 lb), then mahimahi, Coryphaena hippurus, 3,631 kg (8,006 lb), and skipjack tuna, Katsuwonus pelamis with 2,947 kg (6,498 lb). The best catches were made in 1980 when 1,165 fishes weighing 6,499 kg (14,331 lb) were caught.

Catch per Unit of Fishing Effort

The Mele Moku fished on 207 days in 1977, 187 days in 1978, 184 days in 1979, 182 days in 1980, 257 days in 1981, and 214 days in 1982. During the 6 years, it averaged 205.2 fishing days per year or roughly 3.9 days per week. On the average, the Mele Moku managed to catch fish on 131.7 days per year or on 64.2% of its trips.

Table 2 summarizes the catch per unit of effort of the major species in numbers and weight per day fished. Yellowfin tuna, kawakawa, Euthynnus affinis, skipjack tuna, and mahimahi had one or more annual catch rates that exceeded one fish per day during the 6-year period. The average catch rate in numbers for blue marlin was only 0.1 fish per day, tied for last with striped marlin, Tetrapturus audax, shortbill spearfish, T. angustirostris, and wahoo, Acanthocybium solandri. However, since the blue marlin

Table 1.--Mele Moku fish catches in numbers and weight, 1977-82.

Species	1977		1978		1979		1980		1981		1982		Total	
	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg	No.	kg
Blue marlin	16	1,569	28	2,764	17	1,643	24	2,510	37	3,865	35	3,365	157	15,716
Sailfish	--	--	--	--	1	24	--	--	--	--	--	--	1	24
Shortbill spearfish	2	35	7	111	6	88	9	118	32	421	23	320	79	1,093
Striped marlin	--	--	2	50	3	75	18	428	22	546	16	410	61	1,509
Unidentified billfish	1	57	--	--	--	--	--	--	--	--	--	--	1	57
Total billfishes	19	1,661	37	2,925	27	1,830	51	3,056	91	4,832	74	4,095	299	18,399
Kawakawa	355	424	61	93	115	223	47	77	10	10	3	15	591	842
Skipjack tuna	259	565	329	1,088	86	185	305	414	202	631	20	65	1,201	2,948
Yellowfin tuna	83	459	64	1,006	44	742	478	1,565	103	1,332	44	881	816	5,985
Total tunas	697	1,448	454	2,187	245	1,150	830	2,056	315	1,973	67	961	2,608	9,775
Mahimahi	72	561	46	435	54	449	197	1,023	59	528	70	635	498	3,631
Wahoo	21	222	16	196	21	229	34	343	26	284	22	177	140	1,451
Jacks, barracuda gray snapper, and leatherjacket	89	18	188	69	122	13	53	23	122	22	65	45	639	190
Grand total	898	3,910	741	5,812	469	3,671	1,165	6,501	613	7,639	298	5,913	4,183	33,446

Table 2.--Catch of major species in numbers (N) and weight (kg) per day (D) by the Mele Moku, 1977-82.

Species	1977		1978		1979		1980		1981		1982		Average	
	N/D	kg/D	N/D	kg/D	N/D	kg/D	N/D	kg/D	N/D	kg/D	N/D	kg/D	N/D	kg/D
Blue marlin	0.1	7.6	0.1	14.8	0.1	8.9	0.1	13.8	0.1	15.1	0.2	15.7	0.1	12.6
Shortbill spearfish	<0.1	0.2	<0.1	0.6	<0.1	0.5	<0.1	0.6	0.1	1.6	0.1	1.5	0.1	0.8
Striped marlin	--	--	<0.1	0.3	<0.1	0.4	0.1	2.4	0.1	2.1	0.1	1.9	0.1	1.2
Kawakawa	1.7	2.0	0.3	0.5	0.6	1.2	0.3	0.4	<0.1	<0.1	<0.1	0.1	0.5	<0.7
Skipjack tuna	1.3	2.7	1.8	5.8	0.5	1.0	1.7	2.3	0.8	2.4	0.1	0.3	1.0	2.4
Yellowfin tuna	0.4	2.2	0.3	5.4	0.2	4.0	2.6	8.6	0.4	5.2	0.2	4.1	0.7	4.9
Mahimahi	0.3	2.7	0.2	2.3	0.3	2.4	1.1	5.6	0.2	2.0	0.3	2.9	0.4	3.0
Wahoo	0.1	1.1	0.1	1.0	0.1	1.2	0.2	1.9	0.1	1.1	0.1	0.8	0.1	1.2

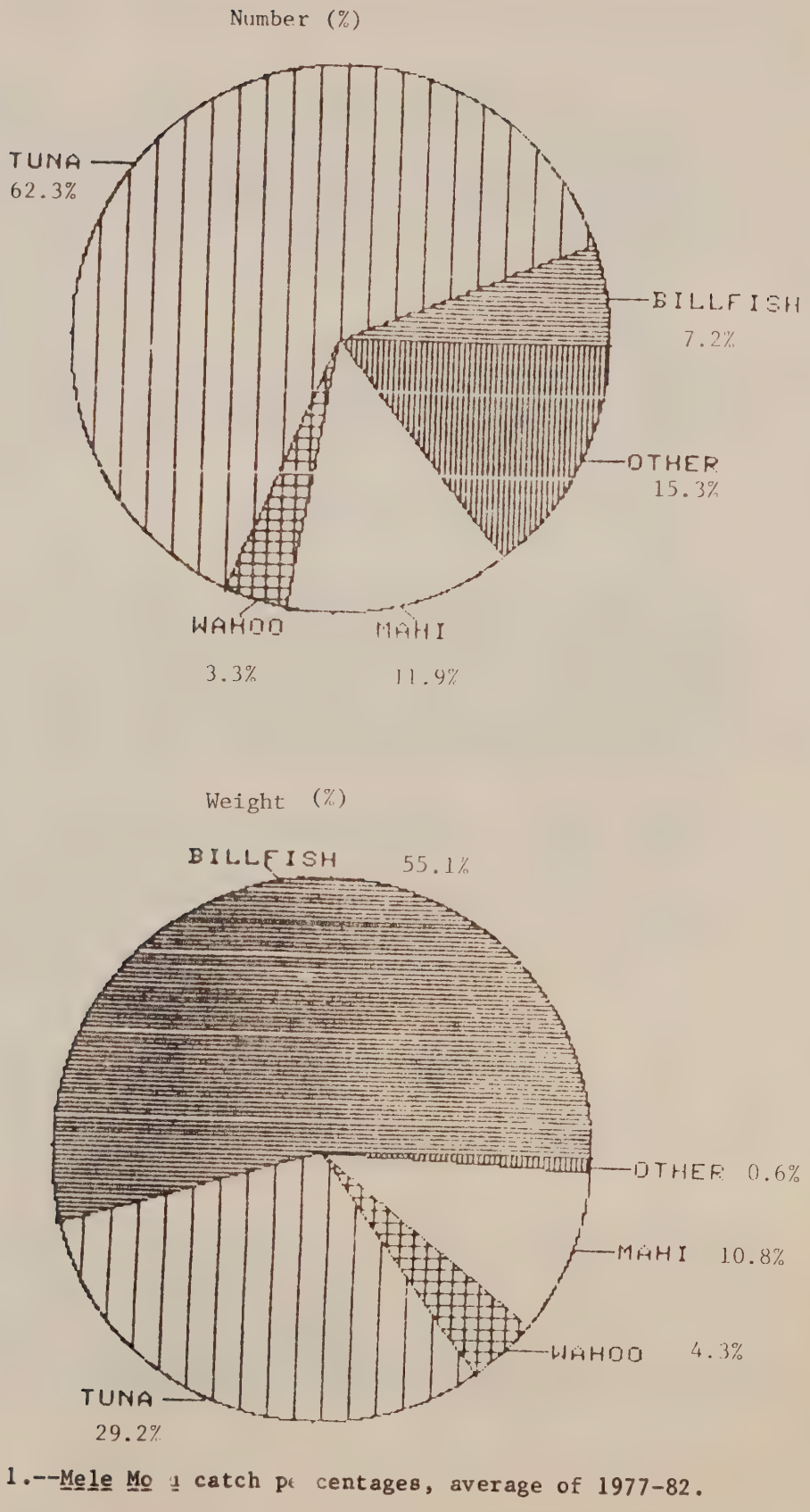

Figure 1.--Mele Mo ɨ catch pe centages, average of 1977-82.

caught were large, their catch rate by weight ranged from 7.6 to 15.8 kg (16.7 to 34.7 lb) per day, the highest of any species.

Based on the number of days fished and the number of each major species caught annually, the calculated number of days it took to catch one fish for the major species caught is shown in Table 3. This measure of fishing effort ranged from 0.6 days for a kawakawa to 103.5 days for a shortbill spearfish.

The seasonal fluctuation of catch rates (number of days to catch a fish) using pooled averages is presented in Table 4 for the major fish species that were caught. The best catch rate for blue marlin was made in the third quarter, and the best for shortbill spearfish was made in the first quarter. For the striped marlin it was the first quarter, the fourth quarter for kawakawa, the second quarter for skipjack tuna, the fourth quarter for yellowfin tuna, the fourth quarter for mahimahi, and the second quarter for wahoo.

Table 3.--The number of days it took the Mele Moku to catch one fish, 1977-82.

Species	1977	1978	1979	1980	1981	1982	Average
Blue marliln	12.9	6.7	10.8	7.6	6.9	6.1	8.5
Shortbill spearfish	103.5	26.7	30.7	20.2	8.0	9.3	33.1
Striped marlin	--	93.5	61.3	10.1	11.7	13.4	[1]38.0
Kawakawa	0.6	3.1	1.6	3.9	25.7	71.3	17.7
Skipjack tuna	0.8	0.6	2.1	0.6	1.3	10.7	2.7
Yellowfin tuna	2.5	2.9	4.2	0.4	2.5	4.9	2.9
Mahimahi	2.9	4.1	3.4	0.9	4.4	3.1	3.1
Wahoo	9.9	11.7	8.8	5.4	9.9	9.7	9.2

[1]1977 was not counted in calculating this average.

Table 4.--Seasonal fluctuations of catch rates in number of days to catch a fish, pooled averages, of major fish species caught trolling by the Mele Moku, 1977-82.

Species	Jan.-Mar.	Apr.-June	July-Sep.	Oct.-Dec.
Blue marlin	16.1	9.1	5.1	7.9
Shortbill spearfish	8.0	11.0	38.6	41.6
Striped marlin	9.1	22.9	347.0	20.8
Kawakawa	3.9	6.5	1.7	1.1
Skipjack tuna	2.0	0.5	3.9	1.0
Yellowfin tuna	2.3	1.6	5.7	0.7
Mahimahi	1.9	3.4	13.9	1.2
Wahoo	13.0	4.8	8.9	22.4

Size Composition of Major Species

The average weights of the major species caught by Mele Moku for 1977 through 1982 are given in Table 5. The averages for the larger marlin, wahoo, and mahimahi are fairly representative of the size groups being caught. There was a large percentage of smaller yellowfin and skipjack tunas caught as shown in the frequency distribution by size groups (Table 6) which is reflected by the relatively low average weights of these two species (Table 5).

Table 5.--Average weights (kg) of major species caught by the Mele Moku, 1977-82.

Species	1977	1978	1979	1980	1981	1982	Average
Blue marlin	98.0	98.7	96.6	104.6	104.5	96.1	99.8
Shortbill spearfish	17.7	15.9	14.7	13.1	13.2	13.9	14.8
Striped marlin	--	25.2	24.9	23.8	24.8	25.6	[1]24.9
Kawakawa	1.2	1.5	2.0	1.6	1.0	5.0	2.0
Skipjack tuna	2.2	3.3	2.2	1.4	3.1	3.3	2.6
Yellowfin tuna	5.5	15.7	16.9	3.3	12.9	20.0	12.4
Mahimahi	7.8	9.4	8.3	5.2	9.0	9.1	8.1
Wahoo	10.6	12.2	10.9	10.1	10.9	8.0	10.4

[1]1977 was not counted in calculating this average.

Table 6.--Size-frequency distribution, by weight categories (kg), of the major fish species caught by the Mele Moku, 1977-82. Only individual weights were used; aggregate weights of two or more individuals were not included.

Year	Blue marlin 0-45	46-91	92-136	137-181	182-227	228-272	273-317	>317
1977	--	12	1	--	1	--	--	1
1978	2	17	4	3	1	--	1	--
1979	--	21	5	1	--	--	--	1
1980	--	16	9	5	2	2	--	--
1981	--	17	10	11	--	--	--	--
1982	4	24	9	1	4	1	1	--

Year	Shortbill spearfish 0-4.5	4.6-9.0	9.1-13.5	13.6-18.0	18.1-22.5	22.6-27.0
1977	--	--	1	--	--	1
1978	--	--	3	3	1	--
1979	--	1	2	3	--	--
1980	--	3	1	2	1	--
1981	--	6	16	8	2	--
1982	--	3	10	8	3	--

Year	Striped marlin 0-23	24-46	47-69
1977	--	--	--
1978	1	1	--
1979	4	2	--
1980	17	8	1
1981	11	12	--
1982	9	5	2

Year	Yellowfin tuna 0-23	24-46	47-69	70-92	93-115	116-138
1977	8	--	--	1	1	--
1978	10	--	2	4	3	--
1979	13	--	2	6	1	--
1980	12	2	7	10	2	1
1981	18	--	10	3	1	--
1982	15	2	11	1	--	--

Table 6.--Continued.

Year	Wahoo					
	0-4.5	4.6-9.0	9.1-13.5	13.6-18.0	18.1-22.5	22.6-27.0
1977	--	7	4	--	1	1
1978	--	4	5	2	1	--
1979	--	6	8	1	--	2
1980	--	14	6	3	1	1
1981	1	9	8	6	--	--
1982	6	8	11	1	--	--

Year	Mahimahi					
	0-4.5	4.6-9.1	9.2-13.6	13.7-18.1	18.2-22.7	22.8-27.2
1977	10	5	15	4	1	--
1978	4	5	10	5	2	--
1979	8	16	9	2	--	1
1980	4	6	19	7	1	1
1981	4	14	17	3	2	1
1982	7	20	21	7	--	--

Year	Skipjack tuna				
	0-2.0	2.1-4.0	4.1-6.0	6.1-8.0	8.1-10.0
1977	19	7	4	1	--
1978	3	1	1	--	1
1979	9	1	1	1	--
1980	14	3	1	1	2
1981	19	3	1	--	1
1982	14	8	1	1	--

Year	Kawakawa		
	0-1.0	2.1-4.0	4.1-6.0
1977	23	3	--
1978	14	--	--
1979	11	3	2
1980	11	3	3
1981	6	1	--
1982	--	2	1

Appendix A.--Mele Moku catches (kg) from April 1979 through December 1982. Includes data from all trips taken by all captains.

Species	1979		1980		1981		1982	
	No.	kg	No.	kg	No.	kg	No.	kg
Blue marlin	28	2,555	35	3,699	38	4,037	44	4,355
Sailfish	1	24	1	32	--	--	--	--
Shortbill spearfish	6	88	9	118	32	421	24	333
Striped marlin	6	138	28	623	23	582	16	410
Total billfishes	41	2,805	73	4,472	93	5,040	84	5,098
Kawakawa	145	226	55	77	10	10	3	15
Skipjack tuna	88	202	309	448	203	634	26	78
Yellowfin tuna	57	770	508	2,437	103	1,332	48	896
Mixed yellowfin and skipjack tunas	--	--	--	--	--	--	28	83
Total tunas	290	1,198	872	2,962	316	1,976	105	1,072
Mahimahi	75	488	228	1,022	63	567	79	732
Wahoo	28	229	50	361	26	284	29	238
Miscellaneous species	3	8	6	23	14	26	13	47
Grand total	437	4,728	1,229	8,840	512	7,893	310	7,187

Appendix B.--Catch of major species in numbers (N) and kilograms (kg) per day (D) by the Mele Moku, 1979-82. These data include trips made by all captains. The total number of fishing days are shown in parentheses.

	1979(246)		1980(295)		1981(267)		1982(284)	
Species	N/D	kg/D	N/D	kg/D	N/D	kg/D	N/D	kg/D
Blue marlin	0.1	10.4	0.1	12.5	0.1	15.1	0.2	15.3
Shortbill spearfish	<0.1	0.4	<0.1	0.4	0.1	1.6	0.1	1.2
Striped marlin	<0.1	0.5	0.1	2.1	0.1	2.2	0.1	1.4
Kawakawa	0.6	0.9	0.2	0.3	<0.1	0.1	<0.1	0.1
Skipjack tuna	0.4	0.8	1.0	1.5	0.8	2.4	0.1	0.3
Yellowfin tuna	0.2	3.1	1.7	8.2	0.4	5.0	0.2	3.2
Mahimahi	0.3	2.0	0.8	3.4	0.2	2.1	0.3	2.6
Wahoo	0.1	1.0	0.2	1.2	0.1	1.0	0.1	0.8

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ASSESSMENT OF THE SOUTH PACIFIC ALBACORE STOCK BASED ON CHANGES IN CATCH RATES OF TAIWANESE LONGLINERS AND ESTIMATES OF TOTAL ANNUAL YIELD FROM 1964 THROUGH 1982

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The stock of albacore, Thunnus alalunga, in the South Pacific supports a sizeable fishery, with total annual catch averaging about 37.0 thousand metric tons (mt). In 1982 it provided a yield amounting to 21% of the world's total albacore harvest. Despite the economic importance of South Pacific albacore, very little is known about its biology and population dynamics. In this note we evaluate the status of the stock using the only means now feasible, the analysis of catch and effort statistics.

Most of the South Pacific albacore catch is taken by Korean and Taiwanese longliners based at Pago Pago, American Samoa. In addition, Japanese longliners targeting on bigeye tuna, T. obesus, and southern bluefin tuna, T. maccoyii, take albacore incidentally. Longline vessels operating from Fiji, the Solomon Islands, and French Polynesia also land a small amount of albacore. The longline-caught albacore, taken at depths near the thermocline, are relatively large fish. About 1 to 2 thousand tons of smaller albacore are caught in surface waters each year by New Zealand trollers.

Table 1 gives estimates of the South Pacific albacore catches each year from the inception of the Japanese longline fishery in 1952, through 1982, the most recent year for which relatively complete figures are available. Catch estimates for 1952-76 are taken from an earlier report by Wetherall (1981); those for 1977-82 are computed from recent FAO statistics and other sources. Over the past two decades there has been relatively little change in the average annual catch. The 5-year mean catch during 1977-81 was 35.8 thousand mt, slightly lower than in the previous 5-year period, and marginally higher than in the two preceding intervals (Table 2).

During the same sequence of 5-year intervals the apparent size of the albacore stock itself has varied inversely with the mean catch (Table 2). The index of abundance used here is the average catch per day of fishing by Taiwanese longliners based at Pago Pago. Because Taiwanese vessels target primarily on albacore, in contrast to most longliners with Korean or Japanese flag, changes in their catch rates should better reflect fluctuations in albacore abundance. Assuming the average Taiwanese catch rates are proportional to albacore stock size, a measure of total effective fishing effort may be computed by dividing this index into the estimated total albacore catch by vessels of all nationality. The effort statistics derived in this manner suggest that the 10% increase in average catch achieved during the first three 5-year periods (Table 2) required a 60% increase in longline effort. Prospects for further expansion of longline fishing on South Pacific albacore would therefore appear very meager at best, and in fact it would seem that a yield almost as large as presently taken could be produced with substantially less effort. A critical assumption here is that the total catch estimates are reasonably precise and that any biases affecting them or the abundance index have been constant. If there have been systematic changes in the completeness or accuracy of catch and effort statistics different conclusions might be drawn.

Table 1.--Estimated annual catches (metric tons) of South Pacific albacore, 1952-82.

Year	Japan	Taiwan	Korea	Other	Total
1952	210	--	--	--	210
1953	1,091	--	--	--	1,091
1954	10,200	--	--	--	10,200
1955	8,420	--	--	--	8,420
1956	6,220	--	--	--	6,220
1957	9,764	--	--	--	9,764
1958	21,558	--	146	--	21,704
1959	19,344	--	456	--	19,800
1960	23,756	--	610	--	24,366
1961	25,628	--	330	--	25,958
1962	38,880	0	599	--	39,479
1963	33,500	608	1,367	--	35,475
1964	21,435	629	2,911	--	24,975
1965	19,305	1,640	6,405	100	27,450
1966	23,401	6,669	10,817	500	41,387
1967	16,640	14,910	13,717	105	45,371
1968	7,707	14,496	10,138	14	32,355
1969	5,559	9,883	9,963	--	25,405
1970	6,560	12,463	11,599	50	30,672
1971	4,339	21,584	14,482	200	40,605
1972	2,796	23,050	14,439	468	40,753
1973	2,381	28,858	17,452	584	49,275
1974	1,847	19,980	12,194	890	34,911
1975	1,045	15,092	9,015	646	25,798
1976	1,906	19,954	12,212	25	34,097
1977	2,378	23,838	11,478	938	38,632
1978	2,744	22,027	11,891	1,617	38,279
1979	2,495	20,172	11,607	907	35,181
1980	2,667	19,224	11,046	843	33,780
1981	[1]2,500	17,705	11,046	1,768	33,019
1982	[1]2,500	17,682	14,504	4,715	39,401

[1]Rough estimates.

Table 2.--Average annual catches of South Pacific albacore during 5-year periods, associated estimates of average catch per day by Taiwanese vessels, and total effective fishing effort.

5-year period	Average annual (mt)[1]	Annual catch per vessel-day (mt)[2]	Total effective annual effort (1,000 vessel-days)
1962-66	33,753	0.851	39.7
1967-71	34,882	0.815	42.8
1972-76	36,967	0.582	63.5
1977-81	35,785	0.606	59.1

[1]Derived from all vessels fishing in South Pacific.
[2]Derived from Taiwanese vessels landing catches at Pago Pago.

Table 3.--Average catches of South Pacific albacore per day of fishing by Taiwanese longliners based at Pago Pago, estimated total South Pacific albacore catches, and derived effective effort statistics, 1964-82.

Year	Catch rate (mt/day)	Total catch (10^3 mt)	Effective effort (10^3 days)
1964	0.826	24.975	30.236
1965	0.803	27.450	34.184
1966	0.923	41.387	44.840
1967	0.941	45.371	48.216
1968	0.782	32.355	41.375
1969	0.842	25.405	30.172
1970	0.808	30.672	37.960
1971	0.702	40.605	57.842
1972	0.643	40.753	63.379
1973	0.675	49.275	73.000
1974	0.452	34.911	77.237
1975	0.483	25.798	53.412
1976	0.659	34.097	51.741
1977	0.626	38.632	61.712
1978	0.771	38.280	49.650
1979	0.542	35.182	64.911
1980	0.529	33.811	63.915
1981	0.560	33.019	58.963
1982	0.778	39.401	50.644

The abundance index and the derived effective effort statistics (Table 3) were used to estimate the relationship between equilibrium yield and longlining effort. Because effort varied from year to year, the average abundance of exploitable albacore in any particular year probably differed from the equilibrium abundance expected had that year's effort, and other factors, been held constant. However, theory suggests that the average abundance in a particular year is approximately the same as the equilibrium abundance which would prevail if the fleet exerted a steady effort level equal to the average of that year's effort and the efforts applied in the preceding several years. Accordingly, following Gulland (1983), an adjusted effort statistic was computed for each year as a weighted average of the current effort and the efforts of the past 2 years. It is assumed here that a year class of albacore contributes significantly to the catch for 3 years.

A surplus production model was fit by least squares to the abundance index and the adjusted effective effort statistics (Fig. 1), providing estimates of the maximum sustainable yield (MSY) and the associated optimum level of longlining effort (FOPT). Also computed was a third parameter, m, which determines the shape of the production curve and, in particular, its behavior under high exploitation rates. The model equation is:

$$Y/F = (MSY/FOPT)\ [m + (1-m)\ (F/FOPT)]^{\frac{1}{m-1}}$$

where, Y/F = expected equilibrium abundance index (average tons of albacore per day of longlining by Taiwanese vessels), and

F = effective effort level.

Fitting this model to the 17 data points for the period 1966-82, the MSY was estimated to be 37.0 thousand mt, and the optimum effort level, FOPT, was calculated to be 56.9 thousand days of longlining (based on the "standard" effectiveness of Taiwanese vessels). The shape parameter, m, was estimated to be 2.4.

By inserting these parameter estimates into the model equation and multiplying by average effective effort, we obtained corresponding estimates of expected equilibrium yield. Values of "observed" equilibrium yield were computed by multiplying the observed abundance indices by their associated average effort. The results are plotted in Figure 2. The curve of predicted equilibrium yield is almost parabolic, but it is obvious from Figure 2 that curves with other shapes would "fit" the data almost as well. (Bear in mind that the curve shown in Figure 2 was not estimated by fitting to the plotted points.)

Sampling biases in the least squares parameter estimates were computed by Quenouille's jackknife procedure (Efron 1982). The resulting corrected ("jackknifed") estimates and associated 95% confidence intervals are:

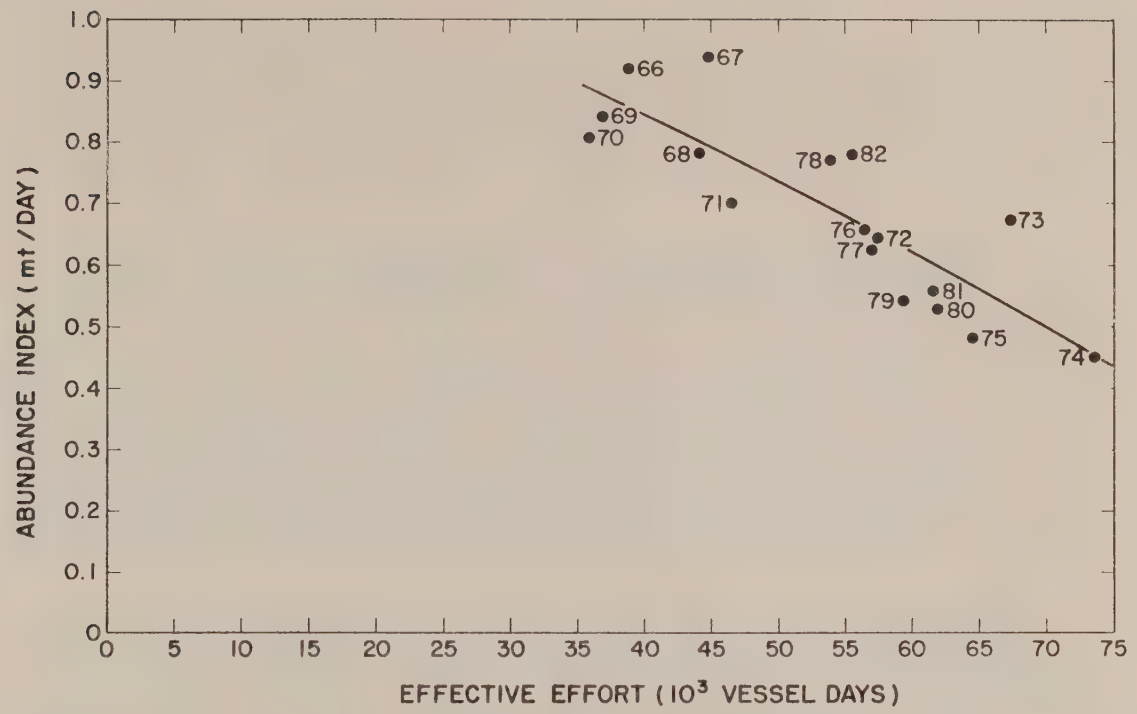

Figure 1.--Relationship between abundance index and estimated effective effort (points), and fitted production model (line).

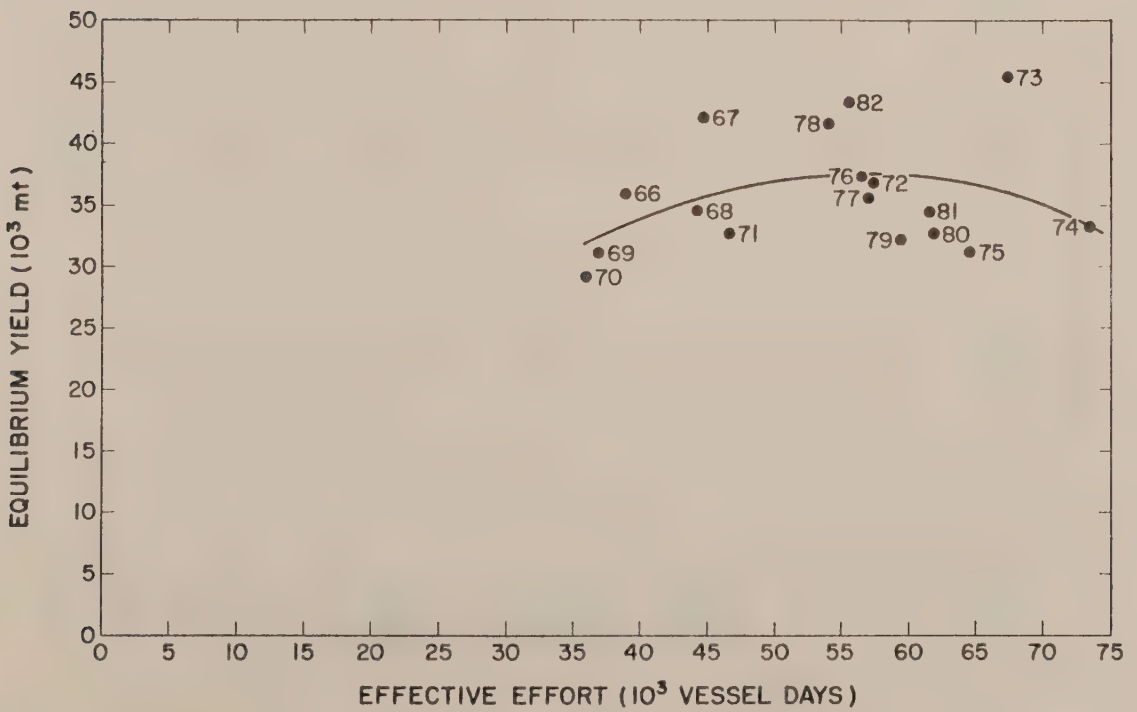

Figure 2.--"Observed" relationship between equilibrium yield and effort (points), and the corresponding equilibrium yield-effort curve implied by the fitted production model (line).

MSY = 37.542	(34.9 , 40.2)
FOPT = 58.215	(49.6 , 66.8)
m = 0.215	($m \leq 2.4$)

Thus the least squares estimate of m is apparently seriously biased, and the implied shape of the surplus production curve in Figure 2 is open to question.

A provisional "unbiased" picture of the relationship between equilibrium yield and effort was computed by jackknifing the production curve around the full-sample least squares estimates of the parameters. Empirical estimates of standard error were also calculated and used to construct an approximate 95% confidence region for equilibrium yield, assuming normality of the jackknifed yield estimates at each effort level.

The resulting 95% confidence band and the "expected" equilibrium yield as a function of longlining effort are shown in Figure 3. While the considerable uncertainty about yield at higher effort levels is clearly indicated, the jackknifed production curve has an inadmissible inflection as effort exceeds the estimate of FOPT, suggesting that this simple jackknifing

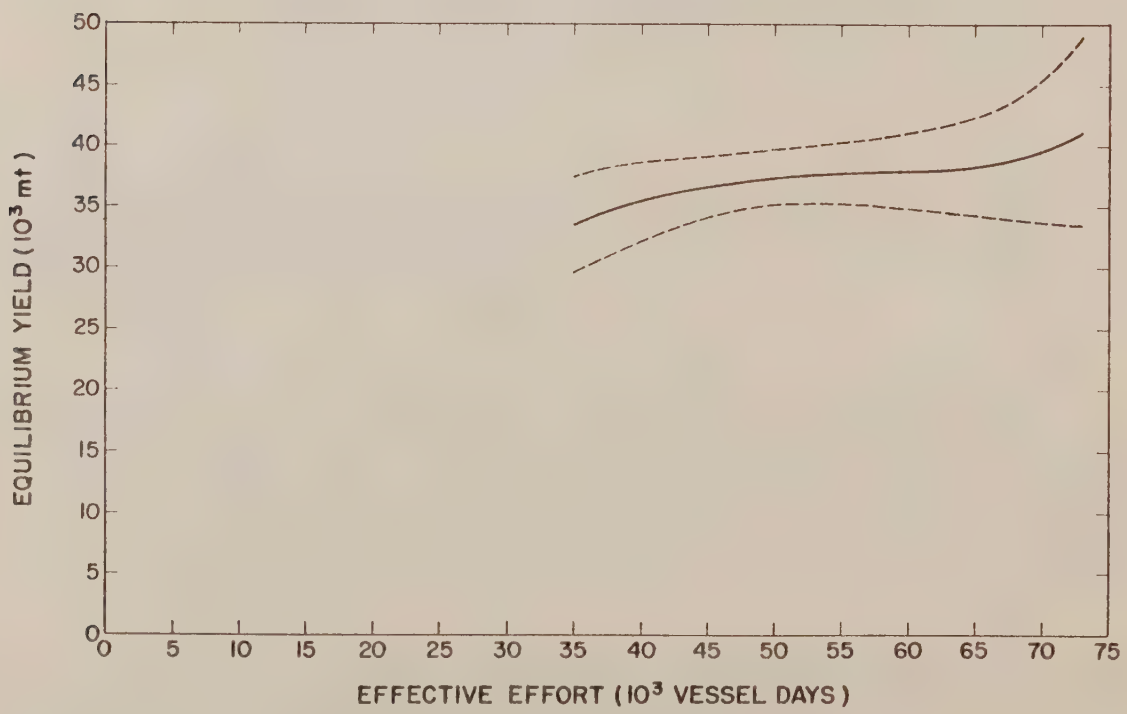

Figure 3.--Jackknifed equilibrium yield-effort curve and estimated 95% confidence region.

procedure is inadequate. Further study of this procedure and development of improved methods is necessary. Note also that the jackknifed production curve and associated 95% confidence band give different results than would be computed by simply inserting the jackknifed parameter estimates and the corresponding confidence limits into the equilibrium yield equation.

The results of this statistical analysis reaffirm the initial conclusion that little improvement in the sustainable yield to longliners can be realized by increasing their effort. Indeed, virtually the same yield could apparently be taken at substantially lower effort than has been exerted in recent years. Reduced effort would likely increase economic efficiency and provide a greater safety margin for the stock.

This assessment was based on several key assumptions which need verification. In particular, further work is needed to demonstrate the validity of the abundance index and to establish the accuracy of the total catch estimates.

Although prospects for increasing the longline catch may be slim, there is a possibility that the total yield of South Pacific albacore can be increased by expansion of effort in the surface fishery, which takes younger fish, on average. Thus an improvement in yield per recruit may be possible. However, on the assumption that the surface and longline fisheries are operating on the same stock, increased harvesting of smaller fish available to the surface fishery would reduce the potential yield to the longliners fishing the older segments of the stock. The degree of impact of a surface fishery on the longline catch rates cannot be predicted very reliably because growth and mortality rates are unknown. Further, the possibility also exists that the albacore available to the surface gear and those vulnerable to longlining are more or less independent groups of fish, in the sense that the surface fishery could be expanded with little harm to longlining. In view of the widespread interest in exploring potentials for a surface fishery, a delineation of stock structure and a study of the various interactions between surface and deepwater groups of albacore would be extremely beneficial.

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SOUTHWEST FISHERIES CENTER

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NATIONAL MARINE FISHERIES SERVICE

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August 1984

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Honolulu, Hawaii

INVENTORY OF U. S. VESSELS IN THE CENTRAL AND WESTERN PACIFIC. PHASE 2—VERIFICATION AND CLASSIFICATION OF HAWAIIAN VESSELS

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INTRODUCTION

A knowledge of the fishing fleets in American Samoa, Guam, Hawaii, and Northern Mariana Islands is an essential and basic element for an understanding of the fishery situation in these areas. For development and management purposes, the fishery agencies in each of these island areas, the Western Pacific Regional Fishery Management Council (Council), and the Southwest Fisheries Center (SWFC) Honolulu Laboratory of the National Marine Fisheries Service voiced a need for an inventory of fishing vessels in the area. With Council funding, the SWFC assembled the public record of vessels from agencies in each island government and the U.S. Coast Guard. The results of this first phase of the study are described in a report (H-84-8) prepared by the SWFC.

As pointed out in that report, the assembled public record of vessels in the central and western Pacific U.S. islands was found to be incomplete, out-of-date in some areas, and insufficient with respect to the use of boats for fishing. Thus, a second phase was initiated in Hawaii cooperatively by the Council, the Division of Aquatic Resources of the Hawaii Department of Land and Natural Resources, and the SWFC. This report provides a summary of the responses received from a questionnaire sent out to vessel owners in Hawaii.

METHODS

It was decided that the best way to separate boats used for fishing from those used for general pleasure, to verify that the boats in the public record were in fact still in use, and to classify the boats by various factors related to fishing, was to mail a questionnaire to individuals who owned vessels registered with the Hawaii Department of Transportation and documented with the U.S. Coast Guard who would potentially use their boats for fishing. Questionnaires were not sent to owners who indicated the following factors on their registration or documentations forms: pleasure-sail, sail and motor, or manual powered; livery; dealer; fee exempt youth group; fee exempt government; passenger carrying; freight only; towing (tug); tanker, oil exploration; passenger-towing; passenger-freight; passenger-towing-freight; and hull material of rubber or fabric.

Following the initial distribution of the questionnaire, one or two reminders were to be sent depending on the response rate. Because of the excellent response rate, only one reminder was mailed.

The questionnaire was developed jointly by the participants in the study and is illustrated in Figure 1. Every attempt was made to include only absolutely essential questions; suggestions to include questions to obtain "nice to know" information were rejected. Also, every attempt was made to make the questionnaire easy to complete by the respondent.

HAWAII VESSEL CLASSIFICATION

I. Preliminary information.

1. Is this boat used for fishing? Yes___ No___

IF YOUR ANSWER IS "NO" STOP HERE AND PLEASE RETURN THE FORM IN THE ENCLOSED ENVELOPE. THANK YOU.

If your answer is "YES" please continue.

2. Would you like to receive a report on the results of this project? Yes ___ No ___

3. Name of boat?_____

4. Where is your boat kept?

a. Moored at_____(harbor name)

b. Trailered and stored at _____
(Town and Island)

II. The following questions will allow us to determine how your boat is used (recreationally, commercially, or something in between) as well as how much it is used.

1. Do you carry fishing passengers for charter? Yes___ No___

2. Do you sell ANY of your catch? Yes___ No___

3. Do you sell more than half of your catch? Yes___ No___

4. Is more than half of your gross income from fishing? Yes___ No___

5. Do you belong to any recreational fishing clubs? Yes_____ No___
(names)

6. On the average, how many days do you fish in a month? Please check only ONE for the Summer Months and only ONE for the Other Months' category:

Summer Months	Other Months
____less than 1 day	____less than 1 day
____1 to 5 days	____1 to 5 days
____6 to 10 days	____6 to 10 days
____more than 10 days	____more than 10 days

III. The following questions will allow us to classify boats according to the fishery in which they are used.

1. Fishing takes place more than 3 miles from land? Yes___ No___

2. Please check the fishing method(s) used on this boat.
a. ___ Troll
b. ___ Rod and reel (casting and spinning)
c. ___ Deep-sea handline (opakapaka, ehu, etc.)
d. ___ Middepth handline (weke-ula, papio, etc.)
e. ___ Shallow handline (omaka, menpachi, akule, etc.)
f. ___ Ika-shibi (night tuna handline)
g. ___ Palu ahi (day tuna handline)
h. ___ Pole-and-line (aku fishing)
i. ___ Tuna longline (shibi-nawa)
j. ___ Lobster traps
k. ___ Shrimp traps
l. ___ Fish traps
m. ___ Crab traps (kona, white, etc.)
n. ___ Crab nets
o. ___ Gill nets (surround, laynet, hukilau)
p. ___ Lobster nets
q. ___ Opelu nets
r. ___ Spear
s. ___ Other (please list)_____

3. If you checked more than one method above, indicate here the most important fishing methods (use the letters from above).
Most important ____ Second most important ___
Third most important ____ Fourth most important ___

IV. To determine the amount of use made of the fish aggregating devices, which the Division has recently deployed, we ask the following.

1. Do you fish around the fish aggregating devices? Yes___ No___

2. List buoy number(s): _____

3. How often do you fish the buoys per month? Check only one in each column:

Summer Months	Other Months
___ less than 1 day	___ less than 1 day
___ 1 to 5 times	___ 1 to 5 times
___ 6 to 10 times	___ 6 to 10 times
___ more than 10 times	___ more than 10 times

4. In general, how much time do you spend fishing a buoy on one visit?_____(hours/minutes)

THANK YOU VERY MUCH FOR TAKING THE TIME TO COMPLETE THIS QUESTIONNAIRE. PLEASE PLACE IT IN THE ENCLOSED POSTAGE PAID ENVELOPE AND RETURN TO US.

Figure 1.--The Hawaii Vessel Classification Questionnaire.

RESPONSE RATE

Although a large number of vessels were eliminated from the survey since they would not be used for fishing at all or to any significant degree, over 12,000 questionnaires were mailed (Table 1). On the first mailing, 4,705 completed questionnaires were received, and, in addition, 81 respondents indicated that their boats were not in use, not seaworthy, no longer in Hawaii, or undergoing prolonged repair, 36 indicated that their boat had sunk, was stolen, or destroyed, and 203 said they had sold their boat. Thus, the total effective rate was 40.0%.

The response rate on the second mailing was about the same (38.2%). Again, most of the respondents completed the questionnaire, but a higher proportion indicated that the boat was no longer in use for various reasons.

Overall, the response rate was 60.6%, 7,042 completed the questionnaire, 145 indicating the boat was no longer in use, 62 indicating that the boat was not usable, and 379 saying that they sold their boat. A response rate of 60.6% is extremely high for such a mail survey. The cooperation of the public in making this survey a success is greatfully acknowledged by the Council, the Hawaii Division of Aquatic Resources, and the National Marine Fisheries Service.

Table 1.--Results on the vessel inventory study.

Category	First mailing	Second mailing	Total
Number mailed	12,578	6,846	12,578
Completed questionnaire	4,705	2,337	7,042
Boat not in use	81	64	145
Sunk, stolen, destroyed	36	26	62
Boat sold, no data	203	176	379
Response rate	40.0%	38.2%	60.6%
Second page only	320	--	320
Not deliverable	928	0	928
Blank questionnaire	14	6	20

SUMMARY OF RESPONSES

The responses to the questionnaire are summarized below by entering the results directly on a facsimile of the questionnaire.

HAWAII VESSEL CLASSIFICATION

I. Preliminary information.

1. Is this boat used for fishing? Yes 5,084 No 1,958

2. Would you like to receive a report on the results of this project? Yes 4,028 No 647 No Response 409

3. Name of boat? Not summarized.

4. Where is your boat kept?[1]

   a. Moored at _____(harbor name)

[1]The place names reported in this question were as indicated on the survey questionnaire. Ambiguities as to location may exist due to alternative spellings of the same moorages. Also, some respondents indicated storage sites on islands different from their mailing addresses.

HARBOR	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
SOUTH POINT	1	1	0.180	0.180
MILOLII	1	2	0.180	0.360
HOOKENA	1	3	0.180	0.541
HONAUNAU	4	7	0.721	1.261
KEALAKEKU, NAPOOPOO, KEEI	4	11	0.721	1.982
KEAHOU, KAHALUU	2	13	0.360	2.342
KAILUA, HONOKAHAU	31	44	5.586	7.928
KAWAIHAE, KAHAKULOA, KOHALA	10	54	1.802	9.730
MAHUKONA	1	55	0.180	9.910
HILO, PAPAIKOU	4	59	0.721	10.631
UNKNOWN	1	60	0.180	10.811
KIHEI	1	61	0.180	10.991
MAALAEA	21	82	3.784	14.775
LAHAINA	10	92	1.802	16.577
MALA WHARD, OLD WHARF, KAHANA	4	96	0.721	17.297
KAHULUI	2	98	0.360	17.658
KAUMALAPAU	4	102	0.721	18.378
MANELE HARBOR	15	117	2.703	21.081
HONOULIWAI	1	118	0.180	21.261
PUKOO HARBOR	2	120	0.360	21.622
KAWELA	1	121	0.180	21.802
KAUNAKAKAI	13	134	2.342	24.144
KOKO HD, MAUNALOA BAY	2	136	0.360	24.505
DIAMOND HD, WAIKIKI, KAHALA	4	140	0.721	25.225
KEWALO BASIN	6	146	1.081	26.306
HONOLULU HARBOR, SAND ISLAND	12	158	2.162	28.468
AIEA	1	159	0.180	28.649
WAIANAE, POKAI BAY	29	188	5.225	33.874
WAILUA	1	189	0.180	34.054
HALEIWA	19	208	3.423	37.477
KANEOHE	36	244	6.486	43.964
HEEIA	20	264	3.604	47.568
KANEOHE	36	300	6.486	54.054
KAHALUU	9	309	1.622	55.676
KAILUA BAY	1	310	0.180	55.856
PORT ALLEN	1	311	0.180	56.036
HANALEI, WAINIHA	3	314	0.541	56.577
KAPAA, WAILUA	2	316	0.360	56.937
NAWILIWILI	6	322	1.081	58.018
KOKO MARINA	7	329	1.261	59.279
HAWAII KAI	49	378	8.829	68.108
ALA WAI	85	463	15.315	83.423
HICKAM	4	467	0.721	84.144
KEEHI LAGOON	68	535	12.252	96.396
PEARL HARBOR	12	547	2.162	98.559
WAHIAWA RESERVE	8	555	1.441	100.000

b. Trailered and stored at [by island of postal residence]

ISLAND

NAME	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	812	.	.	.
HAWAII	757	757	17.720	17.720
MAUI	314	1071	7.350	25.070
LANAI	20	1091	0.468	25.538
MOLOKAI	102	1193	2.388	27.926
OAHU	2734	3927	63.998	91.924
KAUAI	343	4270	8.029	99.953
NIIHAU	2	4272	0.047	100.000

HAWAII

NAME	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	2	.	.	.
CAPTAIN COOK	35	35	4.636	4.636
HAINA	1	36	0.132	4.768
HAKALAU	1	37	0.132	4.901
HALAULA	2	39	0.265	5.166
HALAWA	1	40	0.132	5.298
HAWI	10	50	1.325	6.623
HILO	223	273	29.536	36.159
HOLUALOA	14	287	1.854	38.013
HONALO	2	289	0.265	38.278
HONAUNAU	27	316	3.576	41.854
HONOKAA	25	341	3.311	45.166
HONOKAHAU	1	342	0.132	45.298
HONOKAHOU	1	343	0.132	45.430
HONOKUA	1	344	0.132	45.563
HONOMU	1	345	0.132	45.695
HOOKENA	2	347	0.265	45.960
HOOMALINO	2	349	0.265	46.225
KAHALUU	5	354	0.662	46.887
KAILUA KONA	178	532	23.576	70.464
KAINALIU	4	536	0.530	70.993
KALAMA LANI	2	538	0.265	71.258
KALAOA	6	544	0.795	72.053
KALOPA	2	546	0.265	72.318
KAMUELA	36	582	4.768	77.086
KAPAAU	3	585	0.397	77.483
KAU	2	587	0.265	77.748
KAWAIHAE	7	594	0.927	78.675
KAWANUI	1	595	0.132	78.808
KEAAU	3	598	0.397	79.205
KEAHOU	7	605	0.927	80.132
KEALAKEHE	1	606	0.132	80.265

HAWAII

NAME	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
KEALAKEKUA	24	630	3.179	83.444
KEALIA	1	631	0.132	83.576
KEAUHOU	6	637	0.795	84.371
KEAUKAHA	1	638	0.132	84.503
KEEI KONA	1	639	0.132	84.636
KEOKEA	2	641	0.265	84.901
KEOPUKA	1	642	0.132	85.033
KIHOLO	1	643	0.132	85.166
KOHALA	16	659	2.119	87.285
KOKOIKI	1	660	0.132	87.417
KONALO	1	661	0.132	87.550
KUALAPUU	1	662	0.132	87.682
KUKUIHAELE	1	663	0.132	87.815
KURTISTOWN	1	664	0.132	87.947
LANIHAU	1	665	0.132	88.079
LAUPAHOEHOE	4	669	0.530	88.609
LAWAI	1	670	0.132	88.742
MAHU KONA	1	671	0.132	88.874
MAUNALOA	1	672	0.132	89.007
MILOLII	4	676	0.530	89.536
MOUNTAIN VIEW	1	677	0.132	89.669
NAALEHU	3	680	0.397	90.066
NAPOOPOO	4	684	0.530	90.596
NIULII	1	685	0.132	90.728
OOKALA	2	687	0.265	90.993
OPIHIHALE	1	688	0.132	91.126
PAAUILO	9	697	1.192	92.318
PAAWILA	1	698	0.132	92.450
PAHALA	6	704	0.795	93.245
PAHOA	13	717	1.722	94.967
PAIA	1	718	0.132	95.099
PAPAIKOU	12	730	1.589	96.689
PEPEEKEO	2	732	0.265	96.954
PUAKO	6	738	0.795	97.748
WAIKEA UKA	2	740	0.265	98.013
WAIKOLOA	6	746	0.795	98.808
WAIMEA	7	753	0.927	99.735
WAIOHINA	1	754	0.132	99.868
WAIPIO	1	755	0.132	100.000

MAUI

NAME	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	2	.	.	.
HAIKU	15	15	4.808	4.808
HALIIMAILE	1	16	0.321	5.128

MAUI

NAME	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
HANA	13	29	4.167	9.295
HANAPEPE	1	30	0.321	9.615
KAHANA	1	31	0.321	9.936
KAHULUI	80	111	25.641	35.577
KEANAE	1	112	0.321	35.897
KEAUKAHA	1	113	0.321	36.218
KIHEI	42	155	13.462	49.679
KOKOMO	1	156	0.321	50.000
KULA	6	162	1.923	51.923
LA PEROUSE	2	164	0.641	52.564
LAHAINA	67	231	21.474	74.038
MAKAWAO	10	241	3.205	77.244
MAKENA	2	243	0.641	77.885
NAPILI	2	245	0.641	78.526
OLOWALU	1	246	0.321	78.846
OMOAPIO	1	247	0.321	79.167
PAIA	6	253	1.923	81.090
PAUKUKALO	1	254	0.321	81.410
PUKALANI	15	269	4.808	86.218
PUNA	1	270	0.321	86.538
PUUNENE	3	273	0.962	87.500
WAIKAPU	2	275	0.641	88.141
WAILEA	1	276	0.321	88.462
WAILUKU	36	312	11.538	100.000

LANAI

NAME	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	3	.	.	.
LANAI CITY	17	17	100.000	100.000

MOLOKAI

NAME	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	1	.	.	.
HALAWA	1	1	0.990	0.990
HOOLEHUA	6	7	5.941	6.931
KAHUAAHA	1	8	0.990	7.921
KAIAALU	1	9	0.990	8.911
KAINALU	3	12	2.970	11.881
KALAE	1	13	0.990	12.871
KALAUPAPA	2	15	1.980	14.851
KALOE	1	16	0.990	15.842
KAMALO	2	18	1.980	17.822

MOLOKAI

NAME	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
KAMILOLOA	9	27	8.911	26.733
KAUNAKAKAI	55	82	54.455	81.188
KAWELA	2	84	1.980	83.168
KIPU	1	85	0.990	84.158
KUALAPUU	7	92	6.931	91.089
MAUNALOA	2	94	1.980	93.069
MOLOKAI	1	95	0.990	94.059
PUKOO	3	98	2.970	97.030
WAIALUA	3	101	2.970	100.000

OAHU

NAME	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	7	.	.	.
AIEA	132	132	4.840	4.840
AINA HAINA	8	140	0.293	5.134
AINA KOA	1	141	0.037	5.171
CAMP SMITH	9	150	0.330	5.501
CAMPBELL	1	151	0.037	5.537
CRESTVIEW	1	152	0.037	5.574
EWA	9	161	0.330	5.904
EWA BEACH	72	233	2.640	8.544
FORT SHAFTER	1	234	0.037	8.581
HAIEMALOO	2	236	0.073	8.654
HALEIWA	39	275	1.430	10.084
HAUULA	18	293	0.660	10.744
HAWAII KAI	47	340	1.724	12.468
HEEIA	1	341	0.037	12.505
HICKAM AFB	10	351	0.367	12.871
HONOLULU	789	1140	28.933	41.804
KAAAWA	8	1148	0.293	42.098
KAALAEA	1	1149	0.037	42.134
KAAWA	2	1151	0.073	42.208
KAHALUU	35	1186	1.283	43.491
KAHUKU	2	1188	0.073	43.564
KAHULUI	1	1189	0.037	43.601
KAILUA	219	1408	8.031	51.632
KAIMUKI	24	1432	0.880	52.512
KAINALIU BC	1	1433	0.037	52.549
KALIHI	17	1450	0.623	53.172
KANEOHE	456	1906	16.722	69.894
KAPAHULU	5	1911	0.183	70.077
KAPALAMA	1	1912	0.037	70.114
KEAAU	1	1913	0.037	70.150
KEAUHOU	1	1914	0.037	70.187
KMCAS	2	1916	0.073	70.260

OAHU

NAME	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
KUALOA	1	1917	0.037	70.297
KULIOUOU	3	1920	0.110	70.407
KUNIA	1	1921	0.037	70.444
LAIE	1	1922	0.037	70.480
LANIKAI	1	1923	0.037	70.517
MAILI	11	1934	0.403	70.920
MAKAHA	13	1947	0.477	71.397
MAKAKILO	22	1969	0.807	72.204
MAKIKI	1	1970	0.037	72.241
MANOA	7	1977	0.257	72.497
MCCULLY	1	1978	0.037	72.534
MILILANI	54	2032	1.980	74.514
MOANALUA	7	2039	0.257	74.771
NANAKULI	28	2067	1.027	75.798
NEWTOWN	1	2068	0.037	75.834
NIU VALLEY	1	2069	0.037	75.871
PAAKO	1	2070	0.037	75.908
PALOLO	2	2072	0.073	75.981
PARADISE PARK	1	2073	0.037	76.018
PAUOA	1	2074	0.037	76.054
PEARL CITY	171	2245	6.271	82.325
PEARL HARBOR	7	2252	0.257	82.582
PEARL RIDGE	2	2254	0.073	82.655
PUNALUU	12	2266	0.440	83.095
RAINBOW BAY	1	2267	0.037	83.132
SALT LAKE	3	2270	0.110	83.242
SAND ISLAND	2	2272	0.073	83.315
SCHOFIELD	2	2274	0.073	83.388
ST LOUIS HT	1	2275	0.037	83.425
SUNSET BEACH	8	2283	0.293	83.718
WAHIAWA	90	2373	3.300	87.019
WAIALUA	33	2406	1.210	88.229
WAIANAE	140	2546	5.134	93.363
WAIKANE	4	2550	0.147	93.509
WAILUA	1	2551	0.037	93.546
WAIMALU	3	2554	0.110	93.656
WAIMANALO	46	2600	1.687	95.343
WAIMEA	4	2604	0.147	95.490
WAIPAHU	114	2718	4.180	99.670
WAIPIO	8	2726	0.293	99.963
WHITMORE	1	2727	0.037	100.000

KAUAI

NAME	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
ANAHILA	1	1	0.292	0.292
ANAHOLA	10	11	2.915	3.207

KAUAI

NAME	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
BARKING SANDS	1	12	0.292	3.499
ELEELE	4	16	1.166	4.665
HAENA	1	17	0.292	4.956
HAMAMOULU	1	18	0.292	5.248
HANALEI	23	41	6.706	11.953
HANAMAHI	1	42	0.292	12.245
HANAMAULU	15	57	4.373	16.618
HANAPEPE	8	65	2.332	18.950
KALAHEO	20	85	5.831	24.781
KAPAA	59	144	17.201	41.983
KAPAHI	2	146	0.583	42.566
KAUMAKANI	4	150	1.166	43.732
KEALIA	3	153	0.875	44.606
KEKAHA	19	172	5.539	50.146
KILAUEA	14	186	4.082	54.227
KOLOA	14	200	4.082	58.309
LAWAI	15	215	4.373	62.682
LIHUE	70	285	20.408	83.090
MAKAWELI	4	289	1.166	84.257
NUIMALU	4	293	1.166	85.423
OMAO	2	295	0.583	86.006
PMRF KEKAHA	1	296	0.292	86.297
POIPU	2	298	0.583	86.880
PRINCEVILLE	1	299	0.292	87.172
PUHI	8	307	2.332	89.504
WAHIAWA CAMP	1	308	0.292	89.796
WAILUA	13	321	3.790	93.586
WAIMEA	22	343	6.414	100.000

NIIHAU

NAME	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
MAKAWELI	1	1	50.000	50.000
PUUWAI	1	2	50.000	100.000

II. The following questions will allow us to determine how your boat is used (recreationally, commercially, or something in between) as well as how much it is used.

1. Do you carry fishing passengers for charter?

CHARTER	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	190	.	.	.
NO	4827	4827	98.631	98.631
YES	67	4894	1.369	100.000

2. Do you sell ANY of your catch?

SELL	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	187	.	.	.
NO	3568	3568	72.861	72.861
YES	1329	4897	27.139	100.000

3. Do you sell more than half of your catch?

SELL HALF	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	366	.	.	.
NO	3900	3900	82.662	82.662
YES	818	4718	17.338	100.000

4. Is more than half of your gross income from fishing?

INCOME	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	344	.	.	.
NO	4589	4589	96.814	96.814
YES	151	4740	3.186	100.000

5. Do you belong to any recreational fishing clubs?

CLUBS	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	187	.	.	.
NO	4337	4337	88.564	88.564
YES	560	4897	11.436	100.000

6. On the average, how many days do you fish in a month?

SUMMER

DAYS	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	265	.	.	.
LESS THAN 1 DAY	631	631	13.094	13.094
1 TO 5 DAYS	2651	3282	55.011	68.105
6 TO 10 DAYS	914	4196	18.967	87.072
MORE THAN 10 DAY	623	4819	12.928	100.000

WINTER

DAYS	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	425	.	.	.
LESS THAN 1 DAY	1085	1085	23.288	23.288
1 TO 5 DAYS	2625	3710	56.343	79.631
6 TO 10 DAYS	555	4265	11.912	91.543
MORE THAN 10 DAY	39[illegible]	4659	8.457	100.000

III. The following questions will allow us to classify boats according to the fishery in which they are used.

1. Fishing takes place more than 3 miles from land?

3 MILES	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	428	.	.	.
NO	2476	2476	53.179	53.179
YES	2180	4656	46.821	100.000

2. Please check the fishing method(s) used on this boat.

METHOD	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
TROLL	3400	3400	18.768	18.768
ROD AND REEL	2415	5815	13.331	32.099
DEEP SEA HANDLINE	1585	7400	8.749	40.848
MIDDEPTH HANDLINE	2018	9418	11.139	51.987
SHALLOW HANDLINE	2462	11880	13.590	65.577
NIGHT TUNA HANDLINE	251	12131	1.386	66.963
DAY TUNA HANDLINE	466	12597	2.572	69.535
POLE AND LINE	409	13006	2.258	71.793
TUNA LONGLINE	71	13077	0.392	72.185
LOBSTER TRAPS	63	13140	0.348	72.533
SHRIMP TRAPS	12	13152	0.066	72.599
FISH TRAPS	142	13294	0.784	73.383
CRAB TRAPS	327	13621	1.805	75.188
CRAB NETS	1182	14803	6.525	81.712
GILL NETS	942	15745	5.200	86.912
LOBSTER NETS	294	16039	1.623	88.535
OPELU NETS	84	16123	0.464	88.999
SPEAR	1652	17775	9.119	98.118
OTHER	341	18116	1.882	100.000

3. If you checked more than one method above, indicate here the most important fishing method (use the letters from above).

MOST IMPORTANT FISHING METHOD

METHOD	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	319	.	.	.
TROLL	1595	1595	33.473	33.473
ROD AND REEL	575	2170	12.067	45.540
DEEP SEA HANDLINE	405	2575	8.499	54.040
MIDDEPTH HANDLINE	342	2917	7.177	61.217
SHALLOW HANDLINE	541	3458	11.354	72.571

MOST IMPORTANT FISHING METHOD

METHOD	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NIGHT TUNA HANDLINE	43	3501	0.902	73.473
DAY TUNA HANDLINE	79	3580	1.658	75.131
POLE AND LINE	15	3595	0.315	75.446
LOBSTER TRAPS	5	3600	0.105	75.551
FISH TRAPS	8	3608	0.168	75.719
CRAB TRAPS	10	3618	0.210	75.929
CRAB NETS	168	3786	3.526	79.454
GILL NETS	280	4066	5.876	85.331
LOBSTER NETS	9	4075	0.189	85.519
OPELU NETS	22	4097	0.462	85.981
SPEAR	531	4628	11.144	97.125
OTHER	137	4765	2.875	100.000

SECOND MOST IMPORTANT FISHING METHOD

METHOD	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	1204	.	.	.
TROLL	631	631	16.263	16.263
ROD AND REEL	615	1246	15.851	32.113
DEEP SEA HANDLINE	432	1678	11.134	43.247
MIDDEPTH HANDLINE	484	2162	12.474	55.722
SHALLOW HANDLINE	601	2763	15.490	71.211
NIGHT TUNA HANDLINE	22	2785	0.567	71.778
DAY TUNA HANDLINE	120	2905	3.093	74.871
POLE AND LINE	78	2983	2.010	76.881
TUNA LONGLINE	10	2993	0.258	77.139
LOBSTER TRAPS	3	2996	0.077	77.216
SHRIMP TRAPS	2	2998	0.052	77.268
FISH TRAPS	14	3012	0.361	77.629
CRAB TRAPS	34	3046	0.876	78.505
CRAB NETS	206	3252	5.309	83.814
GILL NETS	214	3466	5.515	89.330
LOBSTER NETS	40	3506	1.031	90.361
OPELU NETS	11	3517	0.284	90.644
SPEAR	303	3820	7.809	98.454
OTHER	60	3880	1.546	100.000

THIRD MOST IMPORTANT FISHING METHOD

METHOD	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	2068	.	.	.
TROLL	443	443	14.688	14.688
ROD AND REEL	385	828	12.765	27.454
DEEP SEA HANDLINE	334	1162	11.074	38.528

MIDDEPTH HANDLINE	450	1612	14.920	53.448
SHALLOW HANDLINE	497	2109	16.479	69.927
NIGHT TUNA HANDLINE	36	2145	1.194	71.121
DAY TUNA HANDLINE	82	2227	2.719	73.840
POLE AND LINE	67	2294	2.221	76.061
TUNA LONGLINE	12	2306	0.398	76.459
LOBSTER TRAPS	7	2313	0.232	76.691
FISH TRAPS	21	2334	0.696	77.387
CRAB TRAPS	39	2373	1.293	78.680
CRAB NETS	176	2549	5.836	84.516
GILL NETS	162	2711	5.371	89.887
LOBSTER NETS	43	2754	1.426	91.313
OPELU NETS	9	2763	0.298	91.611
SPEAR	220	2983	7.294	98.906
OTHER	33	3016	1.094	100.000

FOURTH MOST IMPORTANT FISHING METHOD

METHOD	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	2922	.	.	.
TROLL	337	337	15.587	15.587
ROD AND REEL	239	576	11.055	26.642
DEEP SEA HANDLINE	158	734	7.308	33.950
MIDDEPTH HANDLINE	275	1009	12.720	46.670
SHALLOW HANDLINE	337	1346	15.587	62.257
NIGHT TUNA HANDLINE	34	1380	1.573	63.830
DAY TUNA HANDLINE	47	1427	2.174	66.004
POLE AND LINE	59	1486	2.729	68.733
TUNA LONGLINE	6	1492	0.278	69.010
LOBSTER TRAPS	3	1495	0.139	69.149
FISH TRAPS	20	1515	0.925	70.074
CRAB TRAPS	54	1569	2.498	72.572
CRAB NETS	218	1787	10.083	82.655
GILL NETS	82	1869	3.793	86.448
LOBSTER NETS	43	1912	1.989	88.437
OPELU NETS	5	1917	0.231	88.668
SPEAR	212	2129	9.806	98.474
OTHER	33	2162	1.526	100.000

IV. To determine the amount of use made of the fish aggregating devices, which the Division of Aquatic Resources has recently deployed, we ask the following.

1. Do you fish around the fish aggregating devices?

	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	155	.	.	.
NO	3224	3224	65.409	65.409
YES	1705	4929	34.591	100.000

2. List buoy number(s): the summary below is by the order of entry.

FIRST BUOY ENTERED

BUOY NO.	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	3719	.	.	.
A	7	7	0.513	0.513
AA	32	39	2.344	2.857
B	84	123	6.154	9.011
BB	17	140	1.245	10.256
C	2	142	0.147	10.403
D	3	145	0.220	10.623
E	49	194	3.590	14.212
F	120	314	8.791	23.004
G	12	326	0.879	23.883
H	42	368	3.077	26.960
I	23	391	1.685	28.645
J	1	392	0.073	28.718
K	68	460	4.982	33.700
L	10	470	0.733	34.432
M	16	486	1.172	35.604
N	19	505	1.392	36.996
O	4	509	0.293	37.289
OT	53	562	3.883	41.172
P	21	583	1.538	42.711
Q	11	594	0.806	43.516
R	164	758	12.015	55.531
S	226	984	16.557	72.088
T	153	1137	11.209	83.297
U	90	1227	6.593	89.890
UU	1	1228	0.073	89.963
V	57	1285	4.176	94.139
W	47	1332	3.443	97.582
X	23	1355	1.685	99.267
Z	10	1365	0.733	100.000

SECOND BUOY ENTERED

BUOY NO.	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	4180	.	.	.
A	3	3	0.332	0.332
AA	3	6	0.332	0.664
B	38	44	4.204	4.867
BB	3	47	0.332	5.199
C	2	49	0.221	5.420
D	1	50	0.111	5.531
E	13	63	1.438	6.969
F	64	127	7.080	14.049
G	21	148	2.323	16.372

SECOND BUOY ENTERED

BUOY NO.	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
H	19	167	2.102	18.473
I	10	177	1.106	19.580
K	21	198	2.323	21.903
L	6	204	0.664	22.566
M	10	214	1.106	23.673
N	11	225	1.217	24.889
O	7	232	0.774	25.664
OT	27	259	2.987	28.650
P	14	273	1.549	30.199
Q	14	287	1.549	31.748
R	181	468	20.022	51.770
S	127	595	14.049	65.819
T	51	646	5.642	71.460
U	122	768	13.496	84.956
V	82	850	9.071	94.027
W	38	888	4.204	98.230
X	7	895	0.774	99.004
Y	1	896	0.111	99.115
Z	8	904	0.885	100.000

THIRD BUOY ENTERED

BUOY NO.	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	4543	.	.	.
A	1	1	0.185	0.185
AA	1	2	0.185	0.370
B	9	11	1.664	2.033
D	4	15	0.739	2.773
F	7	22	1.294	4.067
G	5	27	0.924	4.991
H	9	36	1.664	6.654
I	3	39	0.555	7.209
J	1	40	0.185	7.394
K	6	46	1.109	8.503
L	5	51	0.924	9.427
M	2	53	0.370	9.797
N	8	61	1.479	11.275
O	7	68	1.294	12.569
OT	34	102	6.285	18.854
P	10	112	1.848	20.702
Q	6	118	1.109	21.811
R	46	164	8.503	30.314
S	44	208	8.133	38.447
T	61	269	11.275	49.723
U	22	291	4.067	53.789

THIRD BUOY ENTERED

BUOY NO.	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
V	166	457	30.684	84.473
W	76	533	14.048	98.521
X	5	538	0.924	99.445
Z	3	541	0.555	100.000

FOURTH BUOY ENTERED

BUOY NO.	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	4953	.	.	.
A	2	2	1.527	1.527
B	2	4	1.527	3.053
D	1	5	0.763	3.817
E	3	8	2.290	6.107
H	1	9	0.763	6.870
I	2	11	1.527	8.397
K	4	15	3.053	11.450
L	4	19	3.053	14.504
M	1	20	0.763	15.267
N	1	21	0.763	16.031
O	4	25	3.053	19.084
OT	1	26	0.763	19.847
P	5	31	3.817	23.664
Q	4	35	3.053	26.718
R	19	54	14.504	41.221
S	21	75	16.031	57.252
T	12	87	9.160	66.412
U	10	97	7.634	74.046
V	7	104	5.344	79.389
W	6	110	4.580	83.969
X	20	130	15.267	99.237
Z	1	131	0.763	100.000

FIFTH BUOY ENTERED

BUOY NO.	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	5010	.	.	.
B	1	1	1.351	1.351
D	1	2	1.351	2.703
F	1	3	1.351	4.054
G	2	5	2.703	6.757
H	1	6	1.351	8.108
K	1	7	1.351	9.459
M	1	8	1.351	10.811
N	2	10	2.703	13.514

FIFTH BUOY ENTERED

BUOY NO.	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
O	3	13	4.054	17.568
P	4	17	5.405	22.973
R	9	26	12.162	35.135
S	7	33	9.459	44.595
T	6	39	8.108	52.703
U	8	47	10.811	63.514
V	12	59	16.216	79.730
W	14	73	18.919	98.649
X	1	74	1.351	100.000

CUMULATIVE COUNT OF BUOYS ENTERED

BUOY NO.	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
A	13	13	0.422	0.422
AA	36	49	1.168	1.590
B	135	184	4.380	5.970
BB	20	204	0.649	6.619
C	4	208	0.130	6.749
D	10	218	0.324	7.073
E	65	283	2.109	9.182
F	193	476	6.262	15.445
G	40	516	1.298	16.742
H	72	588	2.336	19.079
I	39	627	1.265	20.344
J	2	629	0.065	20.409
K	102	731	3.310	23.718
L	29	760	0.941	24.659
M	30	790	0.973	25.633
N	41	831	1.330	26.963
O	26	857	0.844	27.807
OT	116	973	3.764	31.570
P	58	1031	1.882	33.452
Q	40	1071	1.298	34.750
R	422	1493	13.692	48.443
S	433	1926	14.049	62.492
T	290	2216	9.409	71.901
U	259	2475	8.404	80.305
UU	1	2476	0.032	80.337
V	335	2811	10.870	91.207
W	185	2996	6.003	97.210
X	63	3059	2.044	99.254
Y	1	3060	0.032	99.286
Z	22	3082	0.714	100.000

3. How often do you fish the buoys per month?

SUMMER MONTHS

DAYS	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	3399	.	.	.
LESS THAN 1 DAY	242	242	14.362	14.362
1 TO 5 DAYS	1023	1265	60.712	75.074
6 TO 10 DAYS	245	1510	14.540	89.614
MORE THAN 10 DAYS	175	1685	10.386	100.000

OTHER MONTHS

DAYS	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	3539	.	.	.
LESS THAN 1 DAY	405	405	26.214	26.214
1 TO 5 DAYS	903	1308	58.447	84.660
6 TO 10 DAYS	128	1436	8.285	92.945
MORE THAN 10 DAYS	109	1545	7.055	100.000

4. In general, how much time do you spend fishing a buoy on one visit?

MINUTES	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
NO RESPONSE	3413	.	.	.
10	11	11	0.658	0.658
15-20	11	22	0.658	1.317
25	40	62	2.394	3.710
30-35	25	87	1.496	5.206
40-45	5	92	0.299	5.506
50	156	248	9.336	14.841
60-70	11	259	0.658	15.500
75	51	310	3.052	18.552
85	1	311	0.060	18.612
90	1	312	0.060	18.671
100	317	629	18.971	37.642
125	10	639	0.598	38.241
130	1	640	0.060	38.300
140	1	641	0.060	38.360
150	118	759	7.062	45.422
175	4	763	0.239	45.661
200	289	1052	17.295	62.956
250	90	1142	5.386	68.342
275	1	1143	0.060	68.402
300	136	1279	8.139	76.541
350	41	1320	2.454	78.995
400-435	123	1443	7.361	86.355
450	21	1464	1.257	87.612

MINUTES	FREQUENCY	CUM FREQ	PERCENT	CUM PERCENT
500	52	1516	3.112	90.724
550	6	1522	0.359	91.083
600	58	1580	3.471	94.554
650	4	1584	0.239	94.794
700	17	1601	1.017	95.811
750	2	1603	0.120	95.931
800	31	1634	1.855	97.786
850	1	1635	0.060	97.846
900	15	1650	0.898	98.743
950	1	1651	0.060	98.803
1000	5	1656	0.299	99.102
1100	1	1657	0.060	99.162
1200	7	1664	0.419	99.581
1400	1	1665	0.060	99.641
1600	1	1666	0.060	99.701
2400	4	1670	0.239	99.940
4000	1	1671	0.060	100.000

REMARKS

This report is a simple but detailed compilation of the responses received from the owners of vessels in Hawaii. A report more suitable for distribution to the respondents and the general public will be prepared. In addition, the interrelationships among the answers to the questions and some factors in the original public record will be reported on at a later date.

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August 1984

PROSPECTUS

ESCAPE VENT EXPERIMENTAL PROCEDURE FOR THE SPINY LOBSTER FISHERY UNDER MANAGEMENT OF THE MAGNUSON FISHERY CONSERVATION AND MANAGEMENT ACT

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ESCAPE VENT EXPERIMENTAL PROCEDURE FOR THE SPINY LOBSTER FISHERY UNDER MANAGEMENT OF THE MAGNUSON FISHERY CONSERVATION AND MANAGEMENT ACT

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INTRODUCTION

In September 1983 the Director of the Southwest Fisheries Center Honolulu Laboratory (SWFC) recommended to the Western Pacific Regional Fishery Management Council (Council) that traps used in the Northwestern Hawaiian Islands (NWHI) under the Council's fishery management plan for the spiny lobster fishery of the western Pacific region be required to have escape vents. The catch in the spiny lobster, Panulirus marginatus, fishery presently consists of 30-35% lobsters below the minimum legal size (hereafter referred to as "sublegal") that must then be handled on deck and returned to the sea by the fishers. Experiments carried out by the SWFC staff[1] and experiences in other fisheries (e.g., Pecci et al. 1978) suggest that these sublegals are subject to considerable mortality due to handling, predation immediately upon their return to the sea, and other predation due to displacement from their home territory or preferred habitat.

The Council's spiny lobster plan development team and its Scientific and Statistical Committee recommended to the Council that the efficacy of escape vents should be investigated by the SWFC, and the Council endorsed their recommendations during its February 1984 meeting. This document describes several experimental phases to provide data necessary to determine an optimum size of escape vents and to demonstrate the effectiveness of vented traps.

OBJECTIVE OF THE STUDY

To provide the degree of protection to the stock intended by the minimum size regulation, of 77-mm carapace length (CL), the SWFC believes that the size of the escape vent should be set so that virtually all undersized lobsters could escape. Given normal variation in body shape, clearly this could be reached only at the expense (from the viewpoint of the industry) of escapement of some legal lobsters around the 77-mm CL limit. Thus, the objective of this study is to determine the rate of escapement as a function of escape vent size and carapace length in the area of high escapement rate of sublegals and low to trivial escapement rate of legal sized lobsters.

PREMISES

Experience with escape vents in fisheries for lobsters of the genus Homarus and other Panulirus (Wilder 1949; Fishing Industry News Service 1972; Krouse and Thomas 1975; Fogarty and Borden 1980; Odemar et al.[2]), indicate

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[1]Gooding, R. M. 1982. Predation on surface and bottom released spiny lobster, Panulirus marginatus, in the Northwestern Hawaiian Islands. Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812. Admin. Rep. H-82-1, 20 p. + 4 figs.

[2]Odemar, M. V., R. R. Bell, C. W. Haugan, and R. A. Hardy. 1975. Report on California spiny lobster, Panulirus interruptus (Randall) research with recommendations for management. Draft of a report presented to the California Fish and Game Commission, July 25, 1975, Monterey, Calif., 98 p.

that the catch of legal lobsters increases on an average of 5.9% in terms of number per trap when escape vents are used. Estimation of the optimum escape vent size will be done using the following premise. If a certain escape vent size allows the escapement of 5.9% of legal lobsters in an experimental laboratory stock, a trap so equipped in the field trials should result in a catch of legal lobsters approximately equal to traps without escape vents. For the sake of experimental testing and model building, we are going to assume that an escapement rate of 5% for 77-mm CL lobsters is "low or trivial" and estimate the escape vent that would result in this escapement rate.

CAPSULATED DESCRIPTION OF EXPERIMENTAL PHASES

I. FIRST ESTIMATION OF ESCAPE VENT SIZE

A. Objective: To obtain a gross, first estimate of the escape vent.

B. Procedure: Find escape vent through which 77-mm CL lobsters cannot easily pass.

II. REFINEMENT OF ESTIMATION OF ESCAPE VENT SIZE

A. Objective: To determine a vent resulting in high escapement of sublegals and no more than 5% escapement of legals under laboratory conditions.

B. Procedure:

1. Select appropriate statistical testing procedure and design laboratory trials accordingly.

2. Conduct experiments.

3. Perform statistical analysis to select best vent.

4. Prepare interim report.

III. FINAL ESTIMATION OF ESCAPE VENT SIZE AND FIELD VALIDATION

A. Objectives:

1. To provide a statistical model for the selection of the best escape vent under field conditions based on desired escapement rates for sublegal and legal lobsters.

2. To determine whether there are differences in catch rates of legal and sublegal sized lobsters between experimental and control traps.

B. Procedure:

1. Select appropriate statistical testing procedure and design field trials accordingly.

2. Conduct field trials on RV Townsend Cromwell.

3. Analyze data.

4. Prepare and issue interim report.

IV. COMMERCIAL DEMONSTRATION AND EFFICIENCY STUDY

A. Commercial Demonstration:

1. Objective: To demonstrate efficacy of the optimum escape vent under commercial conditions based on catch rates of legal and sublegal lobsters.

2. Design field trials based on paired t-test statistical procedure.

3. Conduct field trials on a commercial vessel.

4. Analyze data.

5. Prepare and issue interim report.

B. Efficiency Study:

1. Objective: To determine savings in handling time, if any, due to use of traps with escape vents.

2. Formulate statistical testing procedure and design field trials accordingly.

3. Conduct field trials on commercial vessel.

4. Analyze data.

5. Prepare interim report.

V. PREPARATION OF FINAL REPORT(S)

FIRST ESTIMATION OF ESCAPE VENT SIZE

Traditionally, rectangular shaped escape vents have been used with traps set exclusively for the capture of lobster. Recently, there has been some work on circular vents when both lobster and rock crabs are sought (Krouse 1978). Since there is no minimum size limit for slipper lobster, Scyllarides squammosus, which are caught incidentally to spiny lobster in the NWHI fishery, experiments to optimize the vent size will be done only with the spiny lobster, P. marginatus, the major component of the commercial catch.

Experiments with other lobster species suggest that the vertical dimension of the vent is most critical; variations in millimeters significantly influence the escapement curve (Krouse and Thomas 1975; Fogarty and Borden 1980; Paul 1982). The horizontal dimension, though apparently less critical, is commonly relatively large, 152-290 mm (Krouse 1978; Pecci et al. 1978); 100 mm was found to be too small in one study (footnote 2). Since Paul's (1982) experiments conducted at the SWFC's Kewalo Research Facility showed no difference in the ability of male and female spiny lobster to pass through escape vents, this variable will not be considered in the experiment. Research on spiny lobster in California (footnote 2) suggests that the best approach to determining the estimated optimum height is to avoid morphometric methods and merely find an opening through which (1) legal sized animals (77-mm CL for P. marginatus) can pass without damage to their appendages, (2) animals 1 mm larger can pass with some loss of appendages, and (3) animals 2 mm larger are unable to pass.

We will follow the latter approach in obtaining a preliminary estimate of the optimum vertical height of the escape vent. Specifically, we will obtain approximately five live lobsters in each 1-mm size class from 77- to 79-mm CL from the local commercial fleet, and these will be manipulated by hand through openings with heights of from 54 to 60 mm until an estimated optimum size is found.

Supplies needed:

1. Lobsters--approximately 15 (cost-$75)
2. Escape vent material (cost-nil)

REFINEMENT OF ESCAPE VENT SIZE

Once the preliminary estimate of the optimum opening size has been determined, trials will be conducted at the Kewalo Research Facility to obtain a more precise estimate. The typical approach followed in the literature is to take the escape vent found to be satisfactory in the previous step plus one or two alternative sizes, run laboratory trials with animals of known size to determine escapement rate curves by size of lobster for each alternative escape vent, and then to select what appears to be the best escape vent size for introduction into the fishery.

Our experiment at this step will deviate from this traditional procedure in that a statistical technique will be used involving response surface analysis, coupled with analysis of variance. Response surfaces are used in various manufacturing situations to determine the levels of various factors (e.g., grain, yeast, temperature) that will result in the maximum production of some product (e.g., alcohol). For our experiment, we will use the response surface model to estimate the size of the escape vent resulting in a maximum escapement of 5% for 77-mm CL lobsters. The model will also provide estimates of the escapement rate for undersized lobsters. The statistical procedure requires at least three levels of each factor. We will use three escape vent heights (the estimated best height, one which is 1 mm smaller, and one which is 1 mm larger), and size classes in 1 mm increments from 74- to 79-mm CL (three sublegal and three legal size classes).

In statistical terms, the proposed model that will be fitted to the data will be the following quadratic equation

$$ER = b_0 + b_1VS + b_2VS^2 + b_3CL + b_4CL^2 + b_5VS*CL + Error$$

where, ER = escapement rate in percent

b_i = regression coefficients

VS = vent height in millimeters

CL = carapace length in millimeters.

Analysis of variance will be employed to test for escape vent effectiveness while controlling for any learning which may occur during the course of the experiment. Vent sizes will be adjusted as necessary and used in the next phase of the experiment.

A U-shaped concrete tank with continuous water flow will be utilized for the experimental work. To prevent sun blindness in the test animals (Phillips et al. 1980), the tank will be covered with greenhouse shading cloth. Wire mesh partitions will further divide the tank into four separate sections, and in each section suitable habitat will be set up to encourage lobster escapement. With this configuration, separate trials can be run concurrently in each section of the tank.

The black plastic, crab and lobster pot, which has almost completely replaced the wire mesh trap originally used in the NWHI fishery, will be utilized in the experiments. This dome shaped pot is single chambered and is 295 mm high, 980 mm long, and 770 mm wide. Mesh size is 45 x 45 mm. Two funnel entrances are molded into the pot, but these will not be open during the laboratory trials. Two rectangular areas 45 cm above the bottom of the pot and on opposite sides of the pot may be cut out as lobster escapement vents (there are also two circular areas on the top of the traps that may be cut out for escapement of crabs). One of these rectangular areas will be cut out, and an aluminum escape vent of appropriate size will be attached to each trap.

A single trap with one of the three experimental escape vents will be placed in the center of three of the tank sections and stocked with approximately 30 live lobsters consisting of at most 5 individuals in each millimeter size class from 74- to 79-mm CL. In addition as time and availability of animals allow, a trap without an escape vent and with the entrance cones open will be set in the fourth tank section and stocked with lobsters to test escapement through the entrance cones. Spines on the lobsters' tails will be clipped using a binary scheme to identify each millimeter size class. The traps will be stocked with live lobsters in the evening shortly before complete darkness and food will be distributed among the habitat (none in the traps). The next morning shortly after sunrise, the traps will be checked for determination of escapement by size class. We expect to conduct at least five replications each of the three escape vent configurations.

Supplies needed:	Cost:
1. Black plastic pots (3-4)	$95-$130
2. Rebar or other weight	nil
3. Fabricated escape vents	30
4. Lobsters--20 in each millimeter size class, 74-79-mm CL	1,350
5. Food	50
6. Black shade cloth	110
7. Frame materials	185
8. Habitat materials	20
9. Tank dividers	40

FINAL ESTIMATION OF ESCAPE VENT SIZE AND FIELD VALIDATION

As was indicated earlier, the next step undertaken in escape vent studies described in the literature has been to take traps with the selected best escape vent size and to compare them with unvented traps in the field on either research or commercial vessels. Specifically, tests are performed to determine whether there has been a statistically significant reduction in the catch rate of sublegals while there has been no reduction in the catch rate of legal lobsters. While the size of the escape vent may be adjusted following such trials, the design provides no statistical procedure for doing so.

Since the escapement rate of spiny lobsters under field conditions (e.g., variable habitat, a larger and more variable size composition, presence of bait, presence of predators, variable soaking times, possible deformation of the trap during hauling, and, of course, the entrance cones open) could differ considerably from the laboratory situation, we feel that field trials should be conducted to estimate the optimum escape vent size.

Although it is possible to design an experiment that will provide the statistical means of fine tuning the vent height based on what really happens on the fishing grounds, a larger sample size is required and the cost will be greater. The experimental procedure proposed involves the use of the response surface statistical method as was used in phase II, the laboratory trials. The response surface may be explored for the escape vent size resulting in a maximum escapement of sublegal lobsters given some acceptable escapement rate for legal lobsters. Variation in escape vent size in relation to various maximum escapement rates for legal lobsters may also be explored using the response surface model.

Statistical Design

As mentioned earlier, the response surface method requires that three levels of the controlling factors be employed. For the escape vent factor, the three vent heights determined in the laboratory trials will be used. Although it is clear that the carapace length must be included in the model to be able to investigate escapement rate in the area of the legal limit, it is not clear how to do this before the trials are run. It will probably not be practical to consider 1-mm size intervals as in the

laboratory trials because of small catch rates and size variation between control and experimental traps. Nor do we feel that it would be reasonable to establish three arbitrary size classes before conducting the trials, e.g., sublegal, small legal, and large legal sizes. The best procedure would seem to be to measure each lobster and establish size categories based on the catches. The rate of escapement for lobsters in each carapace length class is the catch in the nonvented trap minus the catch in the vented trap divided by the catch in the nonvented trap. Although there is no prior knowledge of what the variance of such an estimate would be, we feel that the robustness of the regression technique should allow significant results using sample sizes of the same order of magnitude as the paired t-tests described below.

The hypothesized response surface model to be used is the same as before, namely

$$ER = b_0 + b_1 VS + b_2 VS^2 + b_3 CL + b_4 CL^2 + b_5 VS*CL + Error$$

where, ER = escapement rate in percent

b_i = regression coefficients

VS = vent size in millimeters

CL = carapace length in millimeters,

but the definition of carapace length is not fixed.

With respect to testing for differences in catch of legal versus sublegal lobsters, the statistical analysis will consist of the application of the paired t-test to both legal catch count and the percentage of sublegals in each control and experimental trap pair for each escape vent height. Such a test is preferable to the conventional t-test in that it is not confounded by a large variance within trap categories (caused by changing lobster density along the trap string). However, if calculated differences are found not to be normally distributed, the Wilcoxon matched-pairs, signed-ranks test will be employed. Statistical analysis is dependent on an adequate sample size. Given the current sublegal catch in the industry of about 30% and an assumed subsequent increase in catch of legal lobsters of approximately 6% using the optimal escape vent configuration (based on other experiments), a sample size of 326 traps would be required to obtain a significance level of 0.01 and a power of 99% for the paired t-test of catch count, or, 978 traps for all three escape vent heights. The research vessel field trials will exceed the minimal required sample size if at least 18 fishing days are completed with 60 traps set each day.

Field Design

The field trials will be conducted on board the NOAA ship Townsend Cromwell at Necker Island using the black plastic crab and lobster trap. Experimental and control (unvented) traps will be placed alternately along a string. The experimental traps on one string will all have vents of the

same height, and two vents will be placed in each trap. This experimental design will allow statistical control for the effect of any changes in lobster density along the string. Baited traps will be set one day and pulled during the early morning of the next day. Data collected will include string and trap number, depth of the set, and the number and length of the lobsters measured to the nearest millimeter carapace length. Catch of other species will also be recorded.

To carry out this step of the experiment, 30 control and 30 experimental traps for each of the three escape vent sizes must be fished for 6 to 9 days. This could be done by setting 180 traps per day for the 6-9 days on a single cruise. The cost of this experiment would be high due to the large number of traps needed and the overtime involved in processing the catch. We estimate that this procedure would cost approximately $12,500 just for gear and overtime. Alternatively, the field design could consist of separate trials of 6-9 days for each escape vent size. This design would use only 60 traps for each trial and moderate amounts of overtime and added cost due to lost gear. We estimate that this field design would cost about $6,000. As a third alternative, separate trials of 6-9 days duration could be run with each trial consisting of 60 traps (30 controls and 10 each of the three escape vent sizes). The cost of this design would be approximately the same as that of the second alternative. However, at the end of each trial, it would be possible to conduct the response surface model analysis and determine whether significant results were obtained. If statistically significant results are obtained at the end of the second or even the first trial, the experiment could be terminated early, thus saving valuable and expensive vessel time. It may be desirable to conduct the three 6-9 day trials of the last two alternatives in a reasonably short period to eliminate any confounding effects due to seasonal changes in catchability or size composition of the lobsters. We opt to conduct the last alternative field design.

This procedure will then result in a response surface that may be used to select the optimum escape vent size for the escapement of legal and sublegal lobsters. A paired t-test will also be employed to test for differences in catch rates of sublegal and legal lobsters between control and experimental traps.

The experimental design could incorporate a potential effect of density of lobsters on the grounds. A factor could be included in the response surface model for catch per control trap of, for example, total spiny lobster or for some combination of sublegal lobster, legal lobster, and berried lobster. The model might then be:

$$ER = b_0 + b_1 VS + b_2 VS^2 + b_3 CL + b_4 CL^2 + b_5 D + b_6 D^2$$
$$+ b_7 VS*CL + b_8 VS*D + b_9 CL*D + b_{10} VS*CL*D \quad .$$

Other experiments could be run to test for the effect of: (1) dominance of larger individuals (the design actually incorporates this effect but the range in size of animals in the experiment could be expanded by using fishing areas known to have larger individuals), (2) presence of potential predators (by running the trials in areas ascertained to have different

levels of potential predators; at least three areas having different potential predator densities would have to be used), (3) habitat (trials run at three distances from known shelter areas or in three areas having different quantities or qualities of lobster shelter), (4) bait quantity in the traps, (5) time between setting and hauling, (6) trap design (wire with 2 x 2 inch mesh, wire with 2 x 4 inch mesh, and black plastic), and (7) escape gap placement and number. Some of these factors would be more subject to experimental variation, require care in carrying out, and probably a greater sample size. Since none of these factors is now subject to management manipulation (indeed some could never be), they will not be incorporated in the design of this experiment.

Supplies needed:	Cost:
1. Black plastic lobster pots (100)	$3,500
2. Escape vents (100)	950
3. Polypropylene rope (if not available from previous cruise)	200
4. Buckets, burlap bags, etc.	150
5. Ballast for traps (20 lb per trap)	500
6. Bridles (3/8 in. polypropylene rope, if needed)	200
7. Buoys and flagpoles (if needed)	?
8. Bait (most available in SWFC cold storage)	100
9. Saw blades	85

COMMERCIAL DEMONSTRATION AND EFFICIENCY STUDY

With successful completion of the laboratory and research vessel experiments and selection of the optimum escape vent height, trials will be conducted on board commercial vessels as a final demonstration of the feasibility and benefit of using escape vents.

Our plan is to conduct two types of experiments on a commercial vessel. The first experiment will be a direct comparison of the catchability of traps with and without escape vents. For the live market commercial lobster fishers generally set 6-8 strings of 35-40 lobster traps per string over an 8-10 day period. With this in mind, the commercial trials will consist of two strings of approximately 40 traps each. Experimental traps with escape vents and the standard traps used by the vessel will be placed alternately along the string. If the commercial vessel uses about 40 traps per string and fishes 6 strings for 8 days, the sample size should be more than sufficient for statistical purposes. Statistics on the catches resulting from the two strings with control and escape vented traps will be collected by an SWFC observer on the commercial boat. Data on catch (number of legal and sublegal lobsters), the ratio of males and females, and number of berried legal and sublegal females will be collected.

The second experiment will be to determine whether handling time is reduced using traps with escape vents, which would then imply a cost savings for the vessel operator. Detailed data on the time spent by the crew in sorting and processing the catch resulting from strings of traps with and without escape vents will be collected. Since the SWFC observer

will not be able to collect data on both handling times and lobster sizes, this experiment must be run separately from the catch-rate and size-composition trials. Because of the limited fishing time on commercial cruises, especially those which bring back live lobsters, this experiment will have to be conducted on a separate cruise. With no prior knowledge of the time differences, we have no statistical basis for estimating sample size, but feel intuitively that 10-15 days using two strings of 40 traps should suffice.

Statistical tests of catch rate and legal to sublegal ratios will be similar to the research vessel experiment. The statistical tests of handling times will involve an analysis of variance.

Supplies and other needs:	Cost:
1. Black plastic traps (100)	$3,500
2. Escape vents (100)	950
3. Bridles and ballast	100
4. Calipers	200
5. Stopwatch	75
6. Food and bunk charges (20 days)	400
7. Vessel participation fee (20 days)	?

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NATIONAL MARINE FISHERIES SERVICE

THE BENEFITS OF PRESERVING ENDANGERED SPECIES: WITH SPECIAL ATTENTION TO THE HUMPBACK WHALE

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Not for Publication

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THE BENEFITS OF PRESERVING ENDANGERED SPECIES:

WITH SPECIAL ATTENTION TO THE HUMPBACK WHALE

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SEPTEMBER 1984

[NOT FOR PUBLICATION]

PREFACE

This report was prepared by Dr. Robert O. Mendelsohn during a month's fellowship at the Southwest Fisheries Center Honolulu Laboratory. The terms of the fellowship were to provide a University faculty member with the freedom to explore the nature of "existence values for marine mammal resources." In particular, we were looking for an analytical review of the economic literature on existence valuation and a conceptual discussion of evaluating or measuring the nonmarket value of endangered species such as the humpback whale or the Hawaiian monk seal.

Mendelsohn's work emphasizes the difficulty in separating nonuse aspects of a species' value from its direct and indirect use values. Mendelsohn takes a critical approach to most attempts to measure existence values for endangered species and natural resources. He further argues that measurement of use value must be sensitive to caveats concerning the type of use envisaged. Mendelsohn also takes a critical view toward non-utilitarian conceptions of value as applied to endangered species.

I believe this report provides the basis for developing more rigorous criteria for evaluating the possibility of measuring the benefits for preserving endangered marine mammals. Although quantitative comparison of dollar values in terms of costs and benefits from protection programs is not the only yardstick for evaluating preservation programs, it provides useful information for the public, user groups, and decision makers. A number of areas for practical application of the criteria suggested by this report exists within the field of marine mammal protection. A number of economists within the National Marine Fisheries Service look forward to further research in this area.

The Southwest Fisheries Center's economics fellowship program emphasizes the academic freedom of its participating scholars. As such, the report has received minimal editing although Dr. Mendelsohn did receive written comments from Center reviewers which he was free to incorporate or reject as he saw fit. Because the report was prepared by an independent faculty fellow, its statements, findings, conclusions, and recommendations are those of Dr. Mendelsohn and do not necessarily reflect the view of the National Marine Fisheries Service.

Samuel G. Pooley
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Honolulu Laboratory
September 11, 1984

ABSTRACT

This paper reviews and critiques the various benefits allegedly generated by endangered species. Although total benefits may be substantial, many of these separate benefits appear to be redundant and some are probably near zero. The most significant benefit of endangered species appears to be nonconsumptive use. Several suggestions are given about how to empirically measure the benefits of endangered marine mammals in the Hawaiian Islands.

INTRODUCTION

This paper is concerned with measuring the benefits of endangered species in general and the humpback whale and monk seal in particular. Although there are virtually no quantitative estimates of the value of any species anywhere (with the possible exception of the whooping crane--see Stoll and Johnson 1984), economists have pondered the potential value of endangered species for about two decades. The benefits of preserving endangered species fall into one of two categories. The most prevalent source arises from a utilitarian perspective--the species may be helpful to man either directly or indirectly. The alternative perspective considers a more altruistic view--that all species should be given the right to exist independently of any usefulness to man himself.

There are many potential ways a species could be beneficial to mankind. (1) There is user value from direct interactions between man and the species. Whether for consumptive activities such as fishing and hunting or nonconsumptive uses such as birdwatching, hiking, or photography, man clearly obtains pleasure, enjoys, and would therefore be willing to pay for close contact with individual species. (2) In addition to direct use, it is possible there are several indirect mechanisms through which the species is helpful to man. For example, the species may control a pest or may be an important link in the food chain for another species man considers valuable. (3) The species may also provide secondary benefits through a communication medium. A wildlife movie, book, or lecture can become a link between the resource and the public. Even without direct contact, the public through this medium can enjoy the species. (4) Some economists argue that some individuals obtain pleasure just from the existence of the species. (5) Other economists argue people obtain pleasure from the knowledge that species will be preserved for future generations--a bequest value. (6) Many naturalists argue that endangered species have scientific value as potential sources of new information about genetics, medicine, and ecosystems.

The considerable uncertainty about the long-term benefits of a species coupled with the irreversibility of extinction has led to yet other values. (7) Wild species have long been a source of genetic and chemical material. A potential value of any species is consequently chemical mining--the extraction of rare biochemicals directly from the plant or animal. (8) Quasi-option value is the benefit of waiting to make an irreversible decision until more information is available. One reason to preserve species is that their destruction is irreversible and may quickly be regretted. (9) Option value has been labeled as the premium people are willing to pay to keep the chance of having a species maintained given there is uncertainty. Each of these nine potential utilitarian values will be discussed in more detail in the forthcoming sections.

Each of the utilitarian benefits can be discussed in terms of annual benefits. If the species survives, it produces a stream of annual benefits from now far into the future. The total value of this stream is the present discounted value of all future benefits. Because this intertemporal evaluation is consistent across all measures (with the possible

exception of quasi-option value and bequest value), the intertemporal quality of most of the benefits is ignored in the following discussions.

Some individuals question whether it is appropriate to judge the value of a species in terms of its usefulness to man. For example, Stone (1972) argues that perhaps nature should be given certain rights of existence. Alternatively, one could extend Rawls' (1971) discussion of income distribution across man to all of nature. Suppose we did not know which of the 30,000 vertebrate species we would be born into (the veil of ignorance), and we were asked how many species should be preserved. If we wanted to minimize our worst outcome (extinction), we would vote to keep all species. Existence would then be an inalienable right which could not be purchased away.

In the remainder of the paper, I argue that direct and indirect use are the principal reasons to maintain an endangered species. The remaining values either are reflections of direct use, and so are already captured (measured), or are too small to be of any consequence. I further argue that although one could endow each species with an inalienable right to exist, a sound philosophical argument can be made for considering the benefits and costs of each species' existence. Since the benefits of keeping a species will rarely be infinite, measurement of these benefits could be quite helpful for making better decisions about how best to allocate our preservation efforts across species.

For organizational convenience, a section is devoted to each of the nine utilitarian sources of benefits arranged in Table 1. Another section is devoted to the philosophical foundation of the right to exist. For each source of benefits, the empirical and theoretical literature on the subject is critically reviewed and preferred methods of measurement for the humpback whale and monk seal are suggested when appropriate.

It should be understood that the focus of this analysis is on the benefits of preserving individual species with dangerously low populations. Although the benefits of protecting wild populations which are not endangered are related to the benefits discussed here, some of the arguments and thus conclusions do not apply to abundant populations.

DIRECT USE

Direct use is the least controversial and most easily measured value of wildlife. There are two types of direct use--consumptive and nonconsumptive. In general, hunting, trapping, and fishing would be consumptive uses of wildlife because the participants use up the resource through their activity. Hiking, birdwatching, whale watching, and photography, in contrast, are generally nonconsumptive uses because the interaction need not harm or reduce the target population. In practice of course, these distinctions may haze as fishermen could release their catch while photographers so harass an animal that it perishes. These fine points aside, there is an important distinction between consumptive and nonconsumptive benefits. For species which are few in number, consumptive use could quickly

Table 1.--Preservation benefits of endangered species.

Use values
Recreation
Direct
Consumptive
Nonconsumptive
Secondary
Bequest
Nonrecreation
Mining
Chemicals
Genetic material
Experiments
Medical
Ecological
Biological
Nonuse values
Indirect
Elimination of pests
Enhancement of desired species
Risk
Option value
Quasi-option value
Existence

lead to extinction as the population falls below a critical minimum (Bachmura 1971). Thus, endangered species are not suited to provide current consumptive benefits. More likely, the potential consumptive benefits of an endangered species are the discounted values of consuming the species sometime in the future when its population is at a healthy number. Thus, many species who have always had a limited habitat (population), or whose habitat has been acquired by other users, will have no consumptive direct use because they will probably never have a sufficiently large population

to support taking. The Hawaiian monk seal, for example, limited to a few remote uninhabited islands of the Northwestern Hawaiian Islands, would likely fall in this category. In contrast, the humpback whale if it can recover like the sperm and gray whales have, may indeed provide consumptive use again in the future. Except in unusual circumstances where man has mismanaged a species terribly, the forces which drove a population near to extinction also limit the species potential for consumptive use. Thus, the humpback whale may sometime be hunted again, but because of its low reproductive rate such hunting could not be widespread. Most endangered species consequently will have low consumptive direct use benefits.

Several authors have discussed the conditions where upon an unregulated renewable resource could be driven to extinction. Unfortunately with common property resources such as a fishery, users tend to undervalue the common resource. Instead of maintaining the resource wisely over time, the common access users acting on individual but not communal interest deplete the stock. If unregulated, the fisheries tend to be driven to a point where minimal harvestable resources remain. Depending upon the cost of harvesting small populations, the fishery can be driven to extinction (Clark 1973; Cropper et al. 1979; Sinn 1982). Another extension of this renewable resource literature includes a discussion of how preservation value could enter the standard fishing model. Plourde (1975), Miller (1978, 1981), Miller and Menz (1979), and Porter (1982) model preservation value as being a value of the stock itself. The larger the value of the stock, the greater is the difference between the private returns to harvest and the social return. Although this literature is not directly pertinent to measuring preservation value, it does demonstrate that market mechanisms may lead to extinction even when preservation values are high enough to justify keeping the species alive.

In contrast, small populations of animals at least potentially could support relatively high quantities of nonconsumptive use. Thousands of people aboard large cruise vessels get the pleasure of viewing whales in Glacier Bay when there may be only a few whales in the whole area. A similar phenomenon with smaller tourist boats occurs off the coasts of Maui, Hawaii, and California. Clearly individuals are willing to pay substantial fees just to be able to view the animals at closer range.

The activities of naturalists who spend a large fraction of their time as volunteers or lower paid professionals observing wildlife is another example of nonconsumptive use. Clearly, these individuals are receiving substantial pleasure from their intimate contact with endangered species. Given the sizable expense and inconvenience endured by these dedicated researchers, the value of the species just to these individuals alone is clearly substantial.

Which species are likely to have large direct use benefits? Are all species of equal value? Although empirical evidence on this issue is limited, the answer is probably no--people distinctly value some species more than others. The eagle, elk, and whale are of distinct value because of their size, complexity, and grace. They are also of great value because they are distinct from other species in ways of interest to man.

The taxonomist's definition of a species is any distinct group which does not interbreed with another group. The taxonomist's observed distinctions across groups, however, may often not be shared by users. Thus, for example, there may be 15 species of wild grass with subtly different characteristics. The destruction of 5 of these 15 grasses may go unobserved to most people. On the other hand, the demise of the bald eagle or humpback whale would be a great loss to many users. Uniqueness is not an all or nothing attribute. Every species by definition is different, but they are not necessarily different in important ways. Users probably care about very unique species but their definition of uniqueness is much broader than the taxonomist's. Only a fraction of the taxonomist's species truly qualify as unique. What is relevant--seals in Hawaii, Hawaiian monk seals, or all seals of a particular type regardless of location?

Three techniques have been used to value recreational direct use: the hedonic travel cost, market demand, and the contingent valuation method. The hedonic travel cost method (Brown and Mendelsohn in press) learns from the choices users make about which sites to visit, i.e., the value they place on the characteristics of sites. Thus, if there were a series of boat trips one could take on which some saw whales and some did not, it would be possible to estimate the individual value of the whales as one of the trip's characteristics. Unfortunately, for humpback whales in Hawaii, the limited choices of destinations in which to encounter the whales would make it difficult to separate the value of the whales from other characteristics of these areas.

Because a great deal of whale watching is done on private boats which charge fees, it is possible to use a market demand approach to estimate the user value of the whales. The marginal whale watching trip is presumably worth the fee the user pays for the last trip (otherwise it would not be the last trip). However, each trip also requires substantial resources in boat capital, fuel, and labor (crew). Assuming whale watching trips are generated competitively, the marginal cost of these services is the price paid for the last trip. Thus, the last trip provides zero net benefits (the benefits equal the cost of access). The value of the whales lies in the value of the inframarginal trips (the trips before the last trip). It is, therefore, necessary to estimate the demand for whale trips. This demand function can only be revealed if there is observed price variation leaving one of two possibilities of attack: a cross-section study across operators or a time series analysis. The relationship of interest in either case is how the number of whale watching trips (person trips) is affected by the price per person trip. The consumer surplus, the area under this demand curve but over the current market price, P_0 would reflect the annual nonconsumptive use value of the resource (Fig. 1).

A third possible approach to measuring direct nonconsumptive use is to ask users what they are willing to pay to obtain access to the whale. The accuracy of the response depends upon the quality of the question because it is necessary that the respondent understand the hypothetical question being posed. Stoll and Johnson (1984) have applied this technique in Texas to value whooping cranes at Aransas National Wildlife Refuge. They found visitors (i.e., users) were willing to pay $4.47 per year to visit the

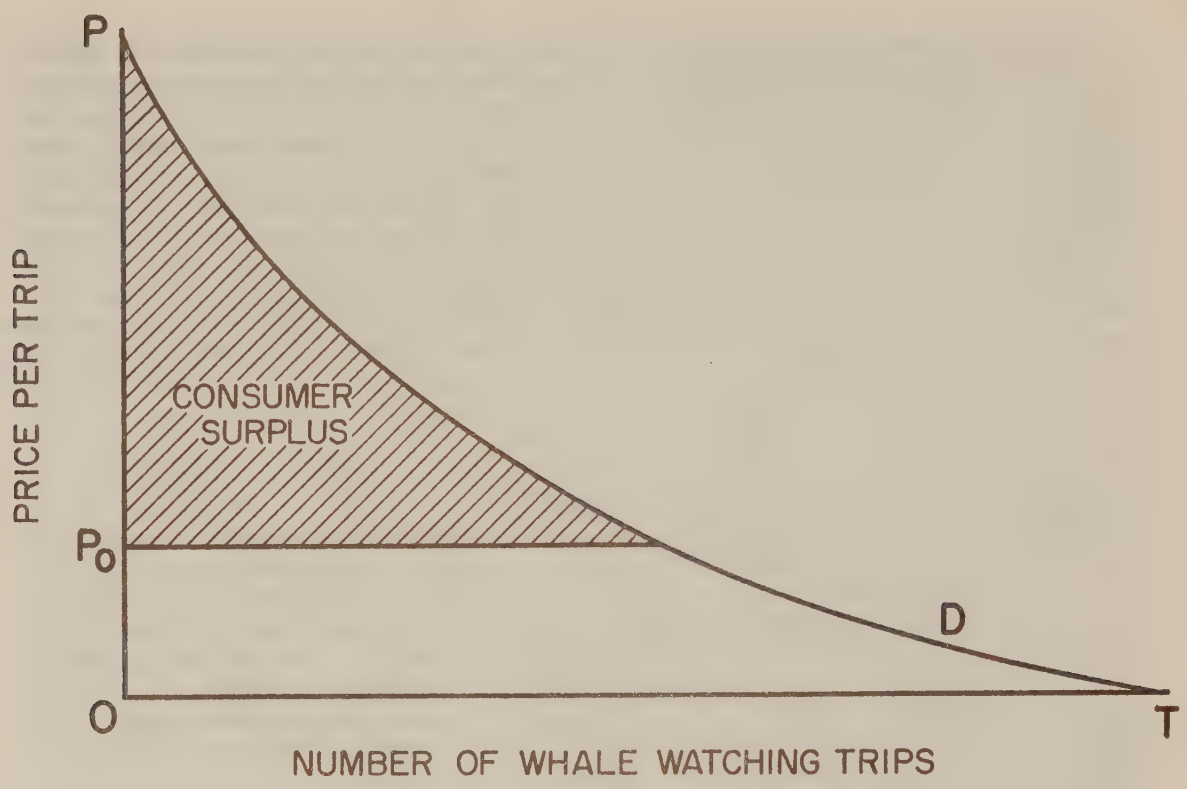

Figure 1.--The demand for whale watching trips.

refuge with whooping cranes present but only $3.07 without whooping cranes. The difference, $1.40, is presumably the value of the rare bird. Given the sample size, this difference is statistically significant at the 5% level. Multiplying by the 60,000-100,000 people per year who visit the refuge suggests the whooping crane provides $84,000-$140,000 annual benefits to Aransas National Wildlife Refuge users alone. Given the migratory nature of the bird, the total value to all "users" including people in other locations is presumably an even larger number.

Clearly the contingent valuation approach to measuring user value could be applied to value endangered species in the Hawaiian Islands. For example, all visitors to Maui and especially those purchasing the whale watching trips could be sampled to evaluate the humpback whale. In particular, it would be interesting to know what people would be willing to pay for an increased probability of seeing a whale, how much more they would pay to see the whale closer, and how much more they might pay to see more than one whale. Given that few visitors have seen a whale before, it might also be interesting to test whether their attitudes before sightings were similar to their responses after experiencing the whale. Finally, it

might be interesting to query whether they perceived that the whale was threatened or harassed by their own approach, and if it was in fact being harmed whether they would prefer such access eliminated.

INDIRECT USE

It is entirely possible that in addition to the direct value of contact between man and a particular animal, the animal provides additional benefits (or costs) through its impact on the ecosystem. For example, seals may eat abalone or lobsters and thereby reduce the population of this desired delicacy. In this case, the seal would be generating an indirect cost measured through another species. On the other side of the ledger, an animal may control a pest. For example, mosquitofish, Gambusia, catch mosquito larvae and control that pest effectively in local areas. Alternatively, fish may be an important source of food for valuable wild or game animals higher in the food chain.

Indirect use captures the relevance of the species to an ecosystem. Because ecosystems involve complex, interrelated balances, the elimination of a species can affect the remaining populations. Indirect use is consequently an important component of the total benefits of many species.

The question we must face, however, is not whether indirect use could ever be important, but rather whether it is likely to be an important component of endangered species. By definition, endangered species populations are few in number and so generally are unable to have a significant impact on the environment. For example, whether or not a population of a hundred small fishes were wiped out is unlikely to have a detectable effect on the higher food chain since such a small source of food is irrelevant to its predators. Similarly, one would think that small populations of predators are unlikely to have any effect on a prey of sufficient population to be a nuisance to man.

This reasoning, however, does have counter examples. A rare moth, Cactoblastis, tends to control the beavertail, Opuntia cactus, in places where the cactus grows naturally. Thus, when the cactus was introduced moth-free to Australia, it promptly overgrew valuable grazing lands. The moth, then introduced into Australia temporarily grew to large populations until the cactus once again was rare. With its food source reduced, the moth then became rare as well. The predator-prey cycle is such that even small populations of predators can check a potential prey pest problem. Critical to this example, of course, is the ability of the rare species to multiply quickly when the pest (food source) reappears.

Although the moth may qualify in this regard, most endangered species are probably incapable of such a rapid recovery of numbers. Thus, it is an open empirical question whether or not indirect use is a sizable component of the benefits of maintaining an endangered species, and the presumption must be that they are not. This is particularly true since most noted endangered species are just below man in the food chain.

SECONDARY USE

It is clear from the market for nature photography, naturalist lectures, and books about nature that people need not directly interact with a site to get value from its existence. Many end users obtain benefits from nature through an intermediary who has gone to the site and converted this experience into an intermediate product: a book, movie, or lecture. There is no question but that the intermediate product has value. One could add up all the money spent on calendars, photographs, books, and movies as a measure of the value of this intermediate product. But the issue is not the value of their products but rather what is the relationship between the natural site or the endangered animal and their product. In particular, there are at least three questions to ask. (1) How much would the total value of secondary products be reduced if a species or natural area disappeared? (2) Is this secondary value already captured by direct use measures? (3) Does the very existence of these secondary products increase or decrease the need to keep the species alive?

If there were no costs to writing and producing a publication (book, photograph, or movie) about an endangered species, the species itself could claim the entire value of the publication. Without the species, the book could not have been written and society would have lost the opportunity to enjoy this good. In reality, of course, it costs a great deal to produce such publications. Without the species, the book would be lost but all the printer's, editors, and writer's time and materials would be freed to print another book. It is the difference in value from the nature book on this particular endangered species and the next best book which is the net contribution of the endangered species.

For example, it is evident that the photographs of Yosemite National Park by Ansel Adams are truly exquisite pieces of art. What if Yosemite had been destroyed before Adams had reached the valley? Would he have instead produced just as beautiful images of alternative sites? Would Yosemite be of less value if Adams had become a fashion photographer instead of producing his nature pictures? It is not at all clear that specific natural sites, in general, and individual endangered species, in particular, generate large net secondary benefits.

Suppose it were agreed that a particular species did contribute significantly to the net value of a book or movie. Is this net value already captured in the direct use measure of the site? The answer depends upon the technique used to measure the value of direct use. For example, if a contingent valuation approach were used and the author or cameraman was interviewed, the value such individuals should place on access to the site is equal to the value of the site in their enterprise. Similarly, if a travel cost technique is used and the artist's relatively high demand for access to the site is measured, this direct use measure could conceivably capture all of the net secondary benefits.

Perhaps the issue of secondary benefits is not that another good must be measured but rather that the measure of direct use must be sensitive to the fact that users creating secondary products may have unusually high

demand for these resources and should be carefully sampled. Thus the representative of a bird society collecting data for an annual lecture, the film maker creating a documentary on an endangered species, and the writer seeking direct contact with nature may all be high direct use demanders not because of their individual tastes but as representatives of a large clientele. It may therefore be important to carefully measure the direct use of these artistic producers to estimate a representative value of the resource.

Although it might appear from the above arguments that little importance is placed on the efforts of naturalists and others to reach the general public through movies, books, lectures, and photographs, such a conclusion should not be drawn. It is entirely plausible that these secondary products have a major beneficial impact on direct use. Certainly many visitors to wild and natural sites have been spurred on by books and documentaries of the very sites they choose to visit. The widespread increased direct use of natural sites in the United States is probably due at least in part to the growth in this country of a vast array of revealing and sensitive books, movies, and photographs of nature. This "inspirational value" on direct use, however, should be captured by intertemporal measures of direct use. As long as the trend in direct use is measured well, these secondary benefits should not be added to direct use measures. To complete my discussion of the role of secondary products on the need to keep species alive, I must introduce the concept of existence value. The discussion of whether or not secondary products increase or decrease existence value is discussed in the next section.

EXISTENCE VALUE

Existence value is a concept first raised by Krutilla (1967) in his often cited article on the benefits of conservation. Existence value is a payment individuals are willing to make to preserve a species (or natural area) which they have no intention of ever visiting. People supposedly obtain pleasure just from the knowledge that a creature or natural wonder is being preserved. Since it is independent of use, existence value clearly should be added to direct use as a measure of total preservation value.

There have been several attempts to measure existence value using contingent valuation methods. Schulze et al. (1983) estimated that 99% of the value of preserving visibility in southwest parks could be existence value. Walsh et al. (1984) find almost 20% of the value of preserving wilderness in Colorado is existence value. Finally, Greenley et al. (1981) estimate that 17% of the value of saving water quality in the South Platte River is existence value.

Although existence value is an intriguing concept, it is easy to be skeptical about the empirical results. After all, existence value is supposed to be completely devoid of potential use value. Is it possible these hypothetical questions were posed to eliminate all potential use? For example, Walsh et al. (1984) ask what percentage of total willingness to pay for wilderness preservation is due to the satisfaction from knowing that it exists as a natural habitat for fish, plants, wildlife, etc. At

first glance, it would appear this question is asking why the respondent would value going to a well known and visited site (because it is natural and not developed). Nowhere in the question is the caveat that the person must not visit the site, since even potential visits are reflected in measures of direct use. Greenley et al. (1981) assume that existence value is what nonusers are willing to pay to preserve water quality. Again there is no careful caveat to prevent direct use from entering the evaluator's judgment. It is highly likely that most, and possibly all, of the measured existence values are merely capturing a component of use value either for the respondent or on behalf of the respondent. As such, it is not at all clear that preservation value is the sum of use and existence value.

In addition to being difficult to quantify, there is reason to suspect that existence value may not even exist. After all, why would people value something with which they have no contact and for which they cannot anticipate contact. What difference would it make if it was not there? How would they even know it was not there when it ceased to exist? Clearly, if a lot of us possessed substantial existence value, it would give a shyster a lot of room to maneuver as he promised to preserve things but never did. Could we rightfully complain? Perhaps we could insist on third party verification that the creature remained. Would we pay a lot to hear a "yes," or would we want to know more. Perhaps a film of the creature and an occasional book would do. But if this is all we want to know of the creature's existence, what would stop the shyster from making several such films and books and then destroying the creature. Do the books and films become a substitute for the long dead creature. It appears that most people's notion of existence value is probably another form of use value, and probably should not be added to direct and secondary use value.

To test for existence value, it is necessary to eliminate potential use from consideration. For example, how much would you pay a millionaire who owned his own island to preserve some small fish in the middle of his property if it was clear that public access would never be granted to the area. Or, how much would you pay to protect an endangered mammal who lived safely on a radioactive island that could not even be approached for a thousand years by human beings. Casual empirical evidence suggests that true existence value is zero.

BEQUEST VALUE

Another source of the benefits of conservation listed by Krutilla (1967) is bequest value. Bequest value is how much an individual is willing to pay to have more capital or land devoted to conservation than alternative uses for his children to enjoy. Like existence value, this concept has been quantified with contingent valuation methods by Walsh et al. (1984) and Greenley et al. (1981). Bequest value was found to be about 18 and 14% of total preservation value in the two studies, respectively. "Bequest value is defined as the willingness to pay for the satisfaction derived from endowing future generations with wilderness resources" (Walsh et al. 1984).

As discussed in the introduction, the present value of use is the discounted value of all future use of the resource. It is very difficult to tell in what way bequest value differs from the string of discounted future benefits of users. Bequest value appears to be future user value called by a different name. Assuming it smells as sweet, it seems reasonable to continue using the concept of present value of use. If future use is properly incorporated into direct use measures, bequest value is redundant and should be ignored.

SCIENTIFIC VALUE

Many fields of science gain empirical knowledge through experiments made under artificial and controlled settings. It is evident, however, that nature itself performs experiments although without the care of controls. Although these natural experiments can be difficult to analyze because of the complexity of the settings, they provide opportunities which might otherwise be lost. For example, what would happen in the long run if one took a cold water mammal and placed it in warm water? Over 200 years, what behavioral and possible physiological changes would be adopted by the animal? Clearly, a controlled experiment along such lines of inquiry could be established but only at considerable cost and a great deal of patience. By studying the endangered monk seal in Hawaii, the answer to this question might be evident with just a modest program.

Endangered species may contain or provide valuable information which would forever be lost upon extinction. The scientific value of endangered species is the present value of all the knowledge the species could provide if it remained alive. Of course, to obtain knowledge from a species it must be studied. With 50,000 vertebrate species and over 2 million animals, it would help to know which species are likely to contain unique scientific information.

Many animals used in laboratory experiments are valuable because they, in one way or another, resemble man. They are also valuable because they are numerous, and so individuals are relatively expendable. This affords scientists additional latitude not permitted on human subjects. Clearly endangered species are unsuitable for this type of work because (perhaps for different reasons) they are just as valuable as humans. Such care has to be taken of their welfare that only gentle experiments can be performed. The gentler the disturbance of a creature, the more subtle his response, and so ever more sensitive measurements are needed on larger populations. Clearly, large population experiments are also difficult with endangered species.

A final note is that scientific value is not generally long lived. Once a species provides the key to a scientific issue, it is no longer useful for that purpose. Thus if an endangered species provides a new biochemical which is then produced by artificial means, it is no longer necessary to preserve the species. The scientific value of a species is the present value of all the clues the population has yet to provide. Once a discovery is made, the scientific value of the species is reduced. (A possible exception to this rule is the discovery that the species is ideal

for a line of experimentation. But as discussed earlier, endangered species are particularly inappropriate for this type of research because of their small numbers.)

CHEMICAL MINING

Wild species have been quite useful over the years to agriculture, medicine, and industry as a source of genetic material and organic compounds. Some 40% of the increase in American agricultural productivity has been attributed to improved genetic strains (Myers 1983). One of the most important tools of these geneticists is a large gene pool--fed by wild stocks. For example, a new strain of wild corn, Zea diploperennis, was recently discovered in the Mexican mountains. Not only is this wild corn resistant to several of the insects, fungi, nematodes, and bacteria which attack our current crops, but it is also a perennial. If this strain can be crossed with current corn into a successful perennial, it could save farmers millions of dollars in plowing and sowing costs.

Wild organisms have also been the source of almost half of the prescription drugs. The rosy periwinkle from tropical forests provides a cure to child leukemia, a Greek species of foxglove controls high blood pressure, a Caribbean sponge is effective against herpes encephalitis, and pufferfish produce compounds which block nerve transmissions, to name just a few of the sources of today's medical chemicals.

Industry, as well, borrows from the wild for many of its products. Tropical coral reefs provide stabilizers and emulsifiers which go into hundreds of products including plastics, polishes, waxes, detergents, etc. Organic chemicals from living plants, phytochemicals, could also serve as a substitute for petroleum-based chemicals if the price of crude oil gets too high.

The fact that man depends upon wild plants and animals is unquestionable. The issue, however, is whether all wild plants and animals should be preserved just because some species have become useful. Ecologists estimate there are 250,000 flowering plants and between 2.5 million and 12 million animal species. To argue that it would be foolish to wipe out all of these wild species is not to conclude that each species is valuable. Even a cursory screening of each of these species would probably be sufficient to identify which species is worth keeping. The probability of finding a valuable species from these vast pools is generally low, so that most wild species cannot be justified as a source of useful chemicals.

The application of chemical mining to endangered plants and animals has the additional problem of destroying individual specimens. Clearly, if the species population is small, it will be a poor source of large quantities of any chemical. Direct chemical mining of the species would either become a small renewable resource effort or a temporary and fatal nonrenewable resource collection. Direct chemical mining of an endangered species could be attractive only if the species could be made to grow quickly with help from man. Even here, the danger of taking the species from the wild to cultivated environment could lead to its accidental destruction.

The most likely avenue by which an endangered species could provide medical, agricultural, or industrial assistance is by being a source of information and not a source of direct chemicals. This perspective is discussed more fully in the previous section on scientific value.

In conclusion, most endangered species have no known chemicals which are of special value for agriculture, medicine, or industry. The few species which are clearly useful, like Zea diploperennis, can justify their existence solely as a source of new genetics or chemical material. However, even in these special cases, the fact that a wild species may be endangered (be close to extinction) lowers its potential value as a chemical source because experimentation is severely limited by the risk of destruction. Even the process of screening the plants for potential benefits must be curtailed by the possibility the search may itself lead to extinction. Thus, although an occasional species has direct and substantial value to agriculture, medicine, or industry, a collection of a thousand unknown but endangered species probably has a low expected value for chemical mining.

QUASI-OPTION VALUE

The concept of quasi-option value was first discussed formally by Arrow and Fisher (1974). They posed a situation where an irreversible decision is being contemplated under uncertainty. The decision could be made now or it could be postponed until more information was available (the uncertainty reduced). The value of waiting is quasi-option value. This concept clearly pertains to endangered species because once the decision for destruction is made it is irreversible. It is also true that the present value of the future streams of benefits of preservation and possible development is uncertain.

As Conrad (1980) notes, quasi-option value is the present value of more information. Because future benefits of information must be discounted, for quasi-option value to be large, we must be learning a lot about the benefits and costs of preservation in the near future. It is only if we can make better decisions about whether to preserve or destroy in the near future, that it pays to postpone making the decision. Given our slow accumulation of information about the long-term value of wild species and the high cost of collecting this information, quasi-option value will tend to be low.

In specific cases, however, quasi-option value could be sizable for a short period of time. For example, suppose a new species of animal or plant were discovered in an untraveled part of the world. A perfect example would be the discovery of Zea diploperennis in Mexico. Until experimentation with this corn is completed, it would probably be foolish to wipe out its habitat. The flow of information coming about the potential usefulness of this species clearly warrants postponing its destruction. Quasi-option value, when it exists, will tend to be short lived. The very process of reducing the uncertainty about the benefits of a species, the source of the quasi-option value, eventually leads to a more or less certain choice. At this point, quasi-option value falls to zero, and the

species is either kept or destroyed based on its known other benefits and costs.

It is also clear that ecosystems or species which do not have sufficient potential to attract research interest will not generate enough new information to warrant a positive quasi-option value. As a meaningful empirical concept, quasi-option value only applies to species which are of current research interest.

OPTION VALUE

Although quasi-option value and option value have similar names and deal with questions of uncertainty, they are distinct concepts. As just discussed, quasi-option value is concerned with intertemporal decisions under uncertainty which are irreversible. Option value, in contrast, is a static concept concerned with valuing projects under uncertainty. As first vaguely expressed by Weisbrod (1964), option value was described as what people would be willing to pay above consumer surplus simply for the option (or chance) to have a good or service. It was widely felt by environmental economists (Cichetti and Freeman 1971; Krutilla and Fisher 1975), that the option value for conservation areas including rare species would tend to be positive. Thus, in addition to the expected value of all the utilitarian benefits listed in this paper, there would be an added "risk premium" made in favor of preservation.

Subsequent research by Schmalensee (1972), Anderson (1981), Graham (1981), Bishop (1982), Mendelsohn and Strang (in press) has shown that option value is not the same as a financial option. With a financial option, a purchaser has the right to buy a good at a specified price in the future. If the price of the good becomes higher than the specified price, the purchaser can exercise his option and a profit. If the price of the good ends up being lower than the specified price, the purchaser of the financial option simply lets his option expire. Option price, in contrast, requires the purchaser to buy the good at the specified price. If the price of the good becomes higher, option price resembles the financial option because the financial option will be exercised. If the price of the good is lower than the specified price, however, the purchaser of option price must buy the good at the specified price. Unlike the financial option, the purchaser must always purchase the good at the specified price. Because the actual price of the good may be lower than the specified price, option price may lock the purchaser into a losing position.

Expected consumer surplus is the measure of what people would pay for the actual service or good they receive. The consumer surplus payment consequently varies with the level of service. The option price payment, in contrast, is the same regardless of the actual level of service. Let us contrast these two measures in a simple example. Suppose people's tastes were such that they would be willing to pay a dollar for each whale they see during a single boat trip. Thus, if no whales are sighted, their willingness to pay would be zero. Under expected consumer surplus, they would pay nothing but under option price they would have to pay a specified price. Similarly, suppose they saw 10 whales (and the average on all trips

is 5), under consumer surplus they would have to pay $10 but under option price they would have to pay only the specified price. Thus the difference between expected consumer surplus and option price is the method of payment. Under consumer surplus, you always pay for what you get. Under option price, you always pay the same amount, whether you get it or not.

Option value is a relevant concept because many public projects are financed from general tax revenues. Thus, one pays a single amount for each park and each species regardless of the actual value of the good. In contrast, the park tends to be valued according to its expected consumer surplus, that is, the actual value to users. Thus our measure of value is inconsistent with our measure of payment. The measure of value is expected consumer surplus, the method of payment is option price. If option price exceeds consumer surplus, public conservation projects should be given a risk premium benefit. If consumer surplus exceeds option price, public conservation projects should be assigned a risk premium cost.

Because option price freezes the purchaser into buying the good at one price, it is not necessarily greater than expected consumer surplus. In fact, option price can be smaller or greater than expected consumer surplus. More importantly, the difference between the two measures relates to the absolute value of the good and subtle changes in the marginal utility of income. As Freeman (1984) has shown, in most circumstances, this difference is likely to be small. As first recommended by Schmalensee (1972), it seems reasonable to accept expected consumer surplus as a close approximation to the ideal measure in an uncertain world.

In contrast to the results of these theoretical inquiries, Greenley et al. (1981), Brookshire et al. (1983), and Walsh et al. (1984) using contingent valuation methods all conclude that option value, the difference between option price and expected consumer surplus, is large and a significant fraction of preservation value. The relevance of these findings, however, is seriously undermined by the definition these authors use for option value. Walsh et al. (1984) define option value as the annual payment required to retain the option of possible future recreation use. This clearly is not option value at all but rather just option price. In the Walsh et al. (1984) paper, option price is clearly less than expected value. In Greenley et al. (1981), option value is defined as what the user would be willing to pay for perfect information about a site next year. Not only is the question vague because the initial uncertainty is not specified, but it is actually a definition of quasi-option value and not option value at all.

On a more theoretical level, Conrad (1980) charges that option value is just the value of perfect information. Option value is clearly positive if this is correct. Conrad, however, has simply redefined option value. He defines an option as the opportunity to delay an irreversible decision until perfect information is available. This is a very different notion from paying a constant price for a good regardless of the true state of nature. Conrad confuses option value with quasi-option value and correctly deals only with the latter.

Another source of confusion is the summary article on option value by Bishop (1982). After an excellent review of the past literature, Bishop attempts to extend the literature by discussing supply side uncertainty. He comes to the conclusion that uncertainty about supply side parameters leads to a positive option value. In a separate article Smith (1983) attempts a similar extension using Cook and Graham's (1977) model of insurance against irreplaceable assets. Smith argues that option value is positive whenever the good in question is irreplaceable.

Clearly, both Bishop's and Smith's arguments could apply to endangered species since both supply uncertainty and irreplaceability are characteristics of endangered species. Both arguments, however, are faulty for different reasons. Bishop's supply side argument raises a special case where option value would be positive. There is little reason to believe, however, that in general people would prefer to make a constant payment for a natural area of variable quality (option price) rather than a payment which varied with the quality of the site (expected value). If the marginal utility of income is positively related to the realized benefits (quality) of the site, option value will be negative. Smith, in turn, confuses option price and Cook and Graham's ransom payment. A ransom payment is what an individual would pay for a good in a certain world. Option price, in contrast, is a certain payment for a good in a random world. The model Smith constructs in his paper implies that the benefits of a project are the same regardless of the outcome of an uncertain world. In such cases, option price and expected value of consumer surplus are also the same. Despite this, Smith asserts he shows option price is larger than expected consumer surplus. The confusion begins, but may not be limited, to the difference between a ransom payment and option price.

A final line of argument raised for a risk premium uses a different notion than option value. For completeness, however, it deserves discussion. Bishop (1978) argues that endangered species should be given a risk premium as part of a game theory model. In Bishop's model, society can or not attempt to protect some endangered species. If it does not protect the species, society might lose it and receive loss y. If it does protect the species, he argues that the worst that can happen is that the protection expense x was unnecessary. As long as $y > x$, the minimax strategy minimizing the worst case, is to protect the species. Bishop pushes this argument further. The potential benefits from the species may have a broad distribution. Evaluating y as the highest possible value of the endangered species, it is likely to be greater than x, the certain cost of foregoing development. Consequently, all endangered species should be preserved unless their existence requires excessive costs.

As Bishop himself notes, this is an entirely conservative approach. Even though the species may have a 1 in 10 million chance of providing benefits, the argument asks us to treat the species as though it provided benefits for certain. The minimax strategy is fine if the worst case is likely to occur but it is much too rigid an approach if the worst case is a rare event. Life would be very tedious if our sole aim was to avoid all the minute chances of having an accident. Clearly the likelihood of a bad accident should be included in our decision making calculus.

A second point not recognized by Bishop is that the worst possible case is not extinction at all. The worst case is that we spend x on preservation and yet the species goes extinct anyway. Since there is no expenditure which will guarantee survival, our best minimax strategy is to not preserve anything regardless of its value.

In conclusion, it appears that option value is small and may be either positive or negative. Given that we have few means available to determine option value, the sensible approach seems to be to ignore it since it does not bias our decisions. Consequently, the appropriate measure of the value of endangered species given uncertainty is the expected value of all benefits.

NONUTILITARIAN BENEFITS

Most of the discussion of endangered species benefits concerns how plants and animals may be useful to man. The underlying notion is that it may be in man's self-serving interest to maintain many species. Some philosophers naturally object to this homocentric viewpoint of nature. Some people do not believe nature exists just for man's pleasure. In fact, Stone (1972) argues that all of nature should be given rights (legal standing) to defend its interests against man.

Existence is primarily a function of adequate resources. Every species needs a certain amount of the correct habitat to survive. The more of that habitat, the higher the probability of survival. Survival can consequently be viewed as an allocation of habitat (resources) problem. Given the total resources of the world, how should they be allocated among species? The problem of survival among species closely resembles issues of income or wealth distribution among people.

Borrowing from Rawls (1971), let's try to determine the optimal allocation of habitat across species. The discussion in the rest of this paper has focused upon how man would like the resources allocated. In this section, we would like to expand the number of voters to include other species. Rawls suggests that one way to think about a fair distribution is to step through a "veil of ignorance." Suppose we did not know that we would be the dominant species. In fact, suppose one could be anywhere in the distribution of species. What allocation of resources across species would one vote for?

Rawls himself argues for a minimax solution. We should try to minimize the worst possible case by making the worst off species as well off as possible. The argument resembles Bishop's (1978) plea to protect all species unless the cost is excessive. Although the definition of excessive cost remains vague, the implication of these arguments is that man (and plants and animals cultivated by man) ought to return substantial habitat to creatures man has little interest in. There should be substantially less commercial forest, agricultural land, grazing acreage, developed land, and probabaly much fewer people. Perhaps only 1% or fewer of the world's population of humans should be allowed to remain.

As discussed by Bishop (1978), the minimax strategy is exceptionally conservative. Why not take a chance that one could become extinct rather than have to share all resources almost equally across species. Almost equal sharing across some 2 to 12 million animal species would almost surely leave most species permanently in a dire subsistence state. Many people would probably prefer to take a chance of dying to get a better life for them and their children rather than having the certainty of permanent poverty. Extinction may be an acceptable risk if the potential rewards to the remaining species are large enough.

Another issue of serious import is how would all the other animals vote. Is man the only animal concerned with its own interest, whereas, the rest of nature maintains a perfect balance? Does nature abound with examples of altruistic behavior across species? I believe there are very few examples where animals have reduced their own welfare consciously to protect other species. Most animals kill as much as they want to eat. They don't willingly go hungry because their food source is weak and needs replenishment. If predators go hungry, it is because they cannot find their source prey, not because they are sorry for them. The law of nature appears to be the law of survival. The law of survival says the dominant animal acts in his self interest. The behavior of most animals would suggest that they would vote for a distribution of resources determined by the interests of the dominant animal. Far from protecting all species, this belief is a foundation for a homocentric utilitarian approach. Man, as the dominant animal, should work to maintain species only if they are valuable to mankind.

CONCLUSIONS

This paper reviews the literature written about conservation and endangered species. The literature identifies nine sources of benefits that living resources might provide man. It is argued that existence value, bequest value, and secondary benefits are redundant and capture benefits measured elsewhere. Other benefits which might be large for some wild species are probably near zero for endangered species because of their small populations. These benefits include direct consumptive use, indirect benefits, scientific information, chemical mining, and quasi-option value. It is further argued that option value could be either positive or negative, is hard to measure, and is probably small. Thus, despite the considerable uncertainty surrounding measurements of the benefits of species preservation, the best approach is to value benefits at their expected value. The major conclusion of the paper is that nonuse values of endangered species are near zero and irrelevant. The focus of empirical work should be upon measuring the use values of endangered plants and animals.

The major benefit of maintaining endangered species lies in nonconsumptive direct use. It is what people are willing to pay to interact with the species in its native habitat. It is the sum of these payments across all users--tourists, hikers, naturalists, writers, moviemakers, etc.--which is the social value of the resource. Projecting this stream of benefits indefinitely into the future and taking its present value yields the social value of each species.

If this hypothesis is correct, that species ought to be preserved because of their nonconsumptive direct use, it gives new perspective to the optimal management of wild species. An animal which people enjoy seeing such as a seal, whale, elk, or buffalo should be protected whether or not it has a small population. The value of the species is not just a function of the size of its population or probability of extinction, but also a question of its appeal. Surely some animals are valuable because they are almost extinct, but some species so closely resemble surviving species that their loss would hardly be noticed. As a point of evidence supporting this notion, even biologists are only aware of a small fraction of the species which go extinct each year. Typical users are probably aware of even fewer of the losses. Some species are clearly worth preserving more than others.

Second, protection of endangered species should not be accomplished to the exclusion of all nonconsumptive use. Surely, if the primary value of maintaining a whale population is the benefits achieved by onlookers, it would be foolish to overprotect the whale by banning all approaches by man. Any overzealous regulation which neutralizes the reason for keeping the animal alive is hardly in the interest of society or the animal. Clearly, one should look for a balance between preserving the animal and maintaining use. Similarly, if the benefits of a species are in viewing rather than scientific information, tour boats should be given preference of access over scientific experimenters.

Third, although the tone of this paper is highly critical of the multiplicity of specialized benefits supposedly provided by endangered species, it is not argued that preservation benefits are likely to be smaller than heretofore expected. It could well be that correct measurement of nonconsumptive direct use will reveal that the preservation value of many endangered species is, in fact, higher than is now expected.

Fourth, nonconsumptive direct use can be measured and evaluated. Contingent valuation, multiple site travel cost, and hedonic travel cost are existing techniques which can be brought to bear on measuring the value of direct use. If, in fact, preservation value is nothing but nonconsumptive use value, then the benefits of preserving individual endangered species can be measured.

Fifth, the benefits and costs of preserving endangered species should be carefully weighed. Current laws rigidly demand all endangered species be preserved. Although, in practice, the administration of this law has been far more flexible than the law itself, Harrington (1981) and Miller and Menz (1979) are correct in their call for a better allocation of resources towards plant and animal protection. The expenditure of a dollar to save a small irrelevant fish could well be the dollar that could have saved an eagle, whale, or brown bear. Society can ill afford to throw its resources carelessly at vanishing habitats or endangered species.

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HISTORY OF SEA TURTLES AT PŌLIHUA BEACH, NORTHERN LANAI

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INTRODUCTION

The only site in the main Hawaiian Islands with a well-documented history of nesting sea turtles is Polihua, a mile-long white sand beach on the northern shore of Lanai (Fig. 1). This is also the only location where the traditional Hawaiian place name is descriptive of eggs on a beach (Poli-hua, literally "eggs in bosom," Pukui et al. 1976). The available information suggests that Polihua was an important breeding site for the Hawaiian green turtle, Chelonia mydas, until the late 1800's or early 1900's. At present, very little nesting has been reported there or anywhere else in the main Hawaiian Islands. Most of the extant nesting by green turtles in Hawaii takes place at French Frigate Shoals, 300 miles to the northwest of Kauai (Fig. 1). Green turtles seasonally migrate to this small isolated site from resident coastal foraging pastures throughout the Hawaiian Archipelago (Balazs 1980). Before 1786, French Frigate Shoals appears to have been unknown, and therefore unexploited, by the people of Hawaii. The area is currently protected as a National Wildlife Refuge. The hawksbill, Eretmochelys imbricata, is a second species of sea turtle that nests in the Hawaiian Islands, but solely in the main islands in small numbers on a few volcanic black sand beaches (Balazs 1978).

There are no reports summarizing the existing knowledge about Polihua and sea turtles, although the significance of the beach has been pointed out in recent publications (Balazs 1975, 1980). In view of the protected status of sea turtles under the U.S. Endangered Species Act, a synthesis of historical information about Polihua and the adjacent coastline of northern Lanai may be helpful to the recovery of the Hawaiian stock. For example, Polihua could prove to be one of the best places in Hawaii to do experimental restocking of green turtles aimed at reestablishing a nesting colony.

REVIEW OF HISTORICAL LITERATURE

Hawaiian folklore relates that Polihua played a key role in the arrival of sea turtles to Hawaiian waters. Beckwith (1970) tells the legend of Aiai, the fish demigod, "marking" a stone at Kaena, the northwestern point of Lanai (Fig. 1). This stone then turned into the first Hawaiian sea turtle, thereby explaining why turtles come to nearby Polihua to lay their eggs (see also Pukui et al. 1976). Tabrah (1976) lists part of an ancient Hawaiian chant as "Ua ono o Pele i kana i'ia o ka honu o Polihua," which is translated as "Delighted, the Fire Goddess (Pele) feasts on flesh of turtles from Egg-nest Cape." The lines of this chant are said to "...celebrate the fame of the turtles who lay their eggs at that point of the coast called Polihua" (see also Emerson 1915; Fornander 1919-1920; Emory 1924). Pukui (1983) records the Hawaiian proverb "Na honu ne'e o Polihua," translated as "The moving turtles of Polihua."

Emory (1924) describes two archaeological sites on the east side of Polihua Valley that are believed to be fishermen's shrines (koa). Except for their proximity to the beach and ocean, no direct evidence was given to relate either of these stone structures to sea turtles. At Kaena-iki, just south of Kaena, Emory (1924) lists a religious stone platform (heiau) said

to be one of the largest of its kind on Lanai. Emory (1924) was unable to determine a name for the heiau since no one had lived in this region of the island for many years.

A series of Hawaiian newspaper articles by Kahaulelio (1902), later translated into English by Mary K. Pukui, contain information about Polihua from the mid- to late-1800's, following abolition of the Hawaiian "kapu system." The relevant sections of the Kahaulelio (1902) account are as follows:

> "Polihua at Lanai was a very famous place for turtle catching. The natives catch them on the sand shore if they need meat. Strangers do too, when they want to visit and see for themselves and if they wanted some to eat. It was a good thing to see this famous fish of the birthplace of my beloved mother who has preceded us yonder when your writer was but a wee child. This was the fish that Pahulu asked the gods not to allow it to have any irritation in its flipper or tail. ... Yes, when you get to Polihua to catch turtles, you need all your strength. It is done thus--go to Polihua in the evening and sleep there and in the early morning, in the twilight, draw close to the edge of the clumps of grass adjoining the sands and there you will see large female turtles returning to the sea. Run as fast as you can to reach a turtle, step with your left foot on the left flipper of the turtle and turn the turtle over with your hands with all your might. If you succeed in turning it over, you are going to eat some turtle meat but if you fail, you'll find yourself in the sea. Your writer has been accustomed as he went to sea frequently to seeing turtles gathered close to the reef. At the time that you see the turtles coming up to breathe, paddle softly until you are very close. The turtle will dive downward and then you'll distinguish it clearly. Dive down and catch it, turn it over as quickly as possible and it becomes very light and easy to land on the canoe. This seems to be the method used by most of the people who relish the greenish luau meat in a turtle. Still the easiest way to catch a turtle is by spearing it and if one speared them at Polihua one caught several times four of them."

A description of turtles at Polihua is also given in Gay (1965) for the early 1900's. Gay (1965) states: "Polihua is located near Kaena Point on the northwest coast of Lanai. It was there that the turtles laid their eggs in the sand above the high-water mark. I have seen turtles that weighed in excess of five hundred pounds on this beach and were capable of carrying three medium-sized persons."

VERIFICATION OF SPECIES

It is important to confirm that the species nesting at Polihua was the green turtle, since this is not clearly stated in the historical literature cited above. Evidence for the green turtle includes the chant quoted by Tabrah (1976) and proverb by Pukui (1983) referring to "honu" (the green turtle) as opposed to honu'ea, the hawksbill (Pukui and Elbert 1971). In

addition, Kahaulelio (1902) and Gay (1965) mentioned the large size of the turtles at Polihua. This description is consistent with the known size of the adult green turtle, but not the smaller adult hawksbill. Kalaulelio (1902) also said that the turtles at Polihua were captured for food, a practice not usually carried out in Hawaii with the hawksbill since this species was considered poisonous (Malo 1951).

REVIEW OF UNPUBLISHED INFORMATION

Since 1972, I was able to gather various unpublished material about Polihua through personal correspondence and interviews with several longtime residents of Lanai. The names of these informants are kept anonymous herein to help insure a continuing flow of information, and also, because some aspects may be culturally sensitive. The individuals involved include native Hawaiians, as well as other reliable members of the Lanai community. The following information comes from these sources.

The stone image of a "turtle god" is reported to be at Polihua. At one time, the exact location was known by at least one elderly person, but windblown sand has apparently covered up the stone. Efforts have been made to locate the stone in recent years since shifting sand may periodically expose it. The success of these efforts is unknown. There are also reports of a turtle petroglyph located at Polihua, on or near a rocky point at the east end of the beach. Sand was also reported to shift back and forth over this site. It is possible that the stone "turtle god" and the turtle petroglyph are, in fact, one and the same. However, stone "fish gods" (kuula) in the Hawaiian culture usually consisted of a smooth upright movable stone. In contrast, petroglyphs were mostly inscribed on large boulders or other stationary rock. Two of the best known Hawaiian petroglyphs depicting sea turtles appear on a boulder at Luahiwa in the interior of Lanai (Emory 1924).

Two persons recalled from memory the catching of turtles on Polihua Beach during the 1920's. The sharp decline in nesting during subsequent years has been attributed to the construction of roads and resulting traffic to the north shore. A dirt road now leads directly to Polihua. Other possible adverse factors to nesting, which have also been speculated upon, include changes in coastal vegetation and heavy erosion at higher elevations (Balazs 1975).

Known or attempted nesting during recent years are listed below. It is possible that some of these reports involve turtles hauled out to bask, rather than to nest. Terrestrial basking is common in the Northwestern Hawaiian Islands, especially at French Frigate Shoals, but rare in the main islands of Hawaii and most other areas of the world (Whittow and Balazs 1982).

- In 1954, a "turtle eggs nest" was reportedly seen at Polihua "behind a large sand dune near a keawe tree."

- In 1968, a turtle was seen "up on a north shore beach."

- In 1971, a turtle was seen right at the water's edge at Polihua.

- On November 23, 1977 at 1000, two large green turtles were seen mating in the sea off Laehi Point, on the northeastern shore of Lanai (Fig. 1).

- On July 31, 1981 at 1300, two "very large turtles" were seen at Polihua "20-30 yards up the beach" near some boulders. No eggs were seen. The observer tried to turn the turtles over, but they proved to be too heavy. "Lots of turtles" were seen offshore. No signs of turtle tracks or digging could be found when the site was examined several days later. This, again, may have been due to the effects of windblown sand. It should be noted that the basking behavior previously mentioned almost always occurs on shore within a few yards of the water, and never 20-30 yards inland.

- In the spring of 1983, a large turtle was seen during the early morning hours returning to the water at the west end of Polihua. The turtle's tracks were traced up the beach and led to a mound of sand (presumably a nesting site). The area was left undisturbed by the observer. A subsequent report indicated that a helicopter service from Maui used this same area of the beach to land tourists. The person who communicated the above information stated he is "convinced" that turtles are again nesting on Lanai.

- During early August of 1983, a large turtle was seen during the daytime in the intertidal shoreline at Awalua, about 2 miles east of Polihua. The observer left the site to tell a nearby companion, but the turtle was gone when they returned.

COASTAL FORAGING PASTURES

Rich coastal foraging pastures for green turtles are believed to occur along the northern and northeastern shores of Lanai. Gay (1965) mentioned that when he lived on Lanai, "turtles were plentiful along the windward side of the island." As quoted earlier, Kahaulelio (1902) said that: "...if one speared them at Polihua one caught several times four of them."

During the 1960's and early 1970's, green turtles were intensively captured off Lanai for commercial markets on Maui. Persons involved in this fishery commuted in small boats between Maui and the mostly remote coastal areas of Lanai. In 1968, a fisherman wrote on his monthly commercial catch report: "This area in 1948-1950 I used to catch at least 100 in 4 to 5 days fishing--for some reason there are no turtles there now."

Major algal food sources used by green turtles in Lanai's foraging pastures consist of Amansia glomerata, Acanthophora spicifera, and Sargassum polyphyllum (sometimes called "limu honu"). The sea grass, Halophila hawaiiana, has also been identified from the stomach of a 96.5-cm adult female green turtle speared by a fisherman in November 1978. This

same animal was found to have large pieces of black and white plastic bags packed throughout its intestines (Balazs 1980).

On October 28, 1982, divers from Molokai visited Laewahie on Lanai's northern shore (Fig. 1). An aggregation of green turtles was seen in about 6 m of water just west of a prominent ferroconcrete shipwreck. One of the turtles, a 56.5 cm juvenile, was captured by hand while it was sleeping under a ledge. The turtle was double tagged (No. 6569, 6570) and released.[1]

The coastal foraging pastures of northern Lanai appear to be an attractive habitat for the recruitment of young green turtles. For example, a 9-month old, 33-cm green turtle reared in captivity and released in 1974 off Oahu was speared 11 months later off northern Lanai. It was found with a group of other similar sized turtles. When the fisherman swam into view, all of the turtles fled except the captive-reared one (Balazs 1980).

RECOMMENDATIONS

No systematic surveys have been undertaken to ascertain the present status of sea turtles on the beach or in nearshore habitat of Polihua and the adjacent coastline. The effect of shifting sands from normally brisk tradewinds may be masking a greater level of nesting than is now being reported from chance sightings. Periodic nighttime searches by a trained observer need to be made from May through August to accurately quantify nesting activity. A series of scuba diving surveys should be carried out to gain a better understanding of the distribution and numbers of turtles dependent upon northern Lanai's nearshore habitat.

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[1] Bill Puleloa, Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawaii, Kaunakakai, Molokai, pers. commun., 1982.

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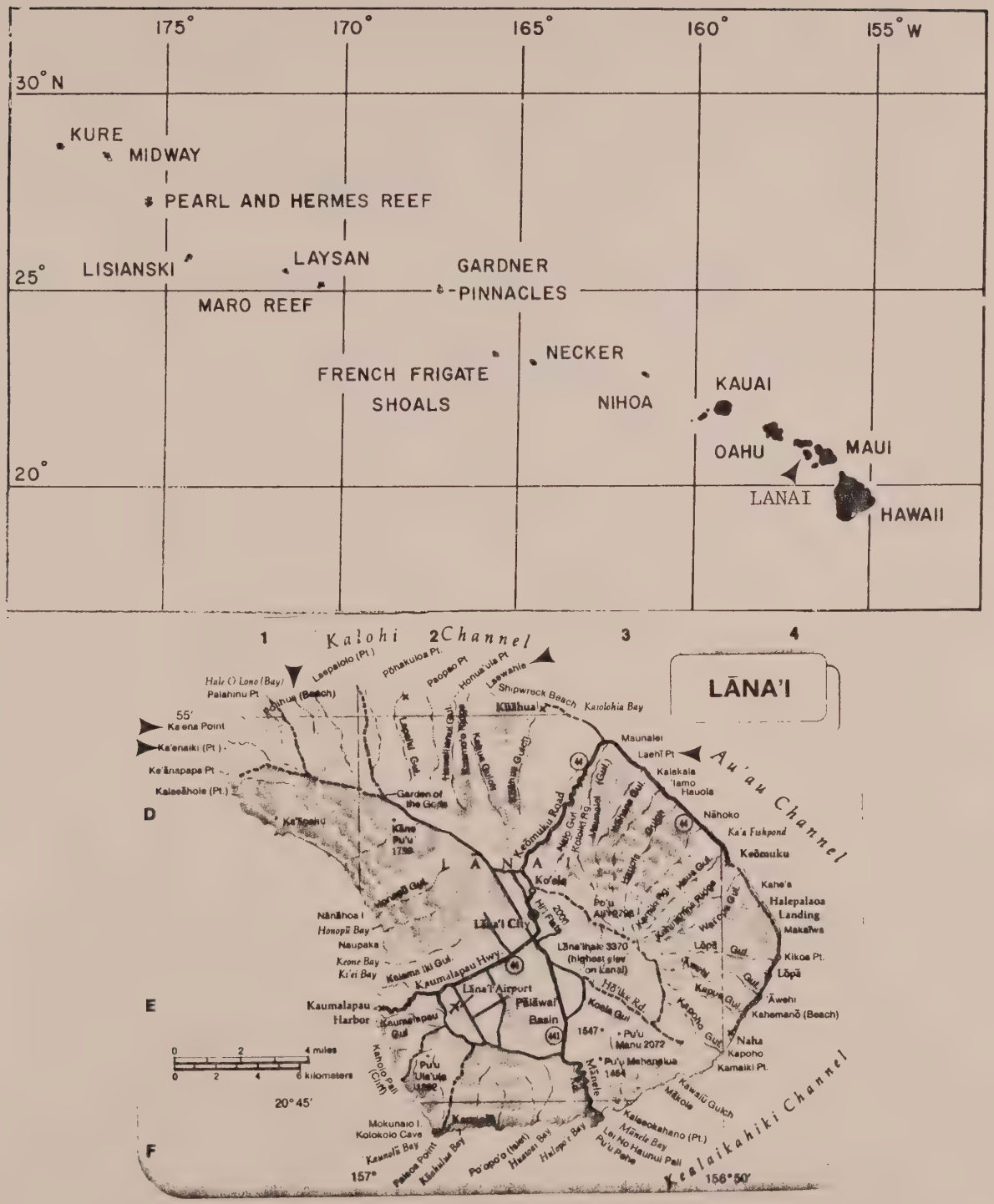

Figure 1.--The Hawaiian Archipelago and an enlarged inset of Lanai (Armstrong 1973).

H-84-16

HL

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NATIONAL MARINE FISHERIES SERVICE

October 1984

National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii

ANNUAL AND AVERAGE MONTHLY TRENDS IN THE CATCH OF BOTTOM FISH SPECIES IN HAWAII 1949-80

Southwest Fisheries Center Honolulu Laboratory
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INTRODUCTION

This data summary was prepared for use by the bottom fish planning team of the Western Pacific Regional Fishery Management Council. A fishery management plan (FMP) under the Magnuson Fishery Conservation and Management Act of 1976 requires a basic description of the relevant fisheries. These summaries were prepared from the monthly reports of the commercial fish landings compiled by the Hawaii Department of Land and Natural Resources, Division of Aquatic Resources (HDAR).

The data cover the 11 "management unit" species included in the draft bottom fish FMP as well as 4 additional species of interest. Additional information on these species, including scientific names and descriptions, can be obtained from the draft bottom fish FMP.

ANNUAL TRENDS

The data have been summarized to show annual historical trends in landings and ex vessel revenue over the years 1949-78. Data for 1979 and 1980 became available after the individual species tables were created. Therefore these latter 2 years have been compiled in one annual table. Table 1 reports the 1979 and 1980 landings and revenue for each of the management unit species, the percent of the total management unit of each, and landings and revenue for four additional species frequently caught by handline methods. Tables 2A through 17A include reported catch (actual landings) in thousands of pounds and metric tons, reported revenue in thousands of dollars, and two "inflation-adjusted" revenue values. Deflated revenue uses the 1967 Honolulu version of the Consumer Price Index to place all values on an equivalent annual basis; adjusted revenue uses the December 1981 version of the price index. The figures show annual reported catch (C) and adjusted revenue (AR).

Figures 1A through 16A clearly show the substantial decline in commercial landings during the 1960's and the significant increase in the 1970's. This pattern is observed for almost all of the individual management unit species. The upward pattern represents three phenomena: an improving market for fresh bottom fish, increased effort by a large number of part-time handline fishers using small boats, and the increased harvest from the Northwestern Hawaiian Islands.

The tables and figures were prepared by Wesley Higuchi, Mathematics Aid, for the Fishery Management Research Program.

Western Pacific Fishery Management Council, 1984. Combined draft fishery management plan, environmental assessment and regulatory input review for the bottom fish and seamount groundfish fisheries of the western

MONTHLY TRENDS

Seasonal trends in the landings of individual bottom fish are clearly identifiable in Figures 1B-16B and Tables 2B-17B. Peak landings and revenue are in December, reflecting the strong influence of Hawaii consumers on the market. This is particularly true for the "red fish" such as onaga and opakapaka. However, some species, such as the shallower water forms (kahala, ulua, and uku) have stronger spring and summer seasons which is probably related to their availability. The figures show average monthly reported catch (C) and revenue (R) in current dollars.

Table 1.--Bottom fish landings, 1979 and 1980 (Source: Hawaii Division of Aquatic Resources, monthly tabulations (preliminary)).

Species	1979		1980		Percent of catch	
	Catch in thousands of pounds	Revenue in thousands of dollars	Catch in thousands of pounds	Revenue in thousands of dollars	1980	1949-78
Management unit	655.9	$1,118.0	666.1	$1,071.7	100.00	100.00
Ehu	21.8	47.8	18.3	38.2	2.75	5.01
Gindai	3.6	4.8	2.2	3.5	0.33	0.24
Hapuupuu	64.9	89.0	55.1	64.8	8.27	7.22
Kahala	83.6	58.9	49.6	28.2	7.45	14.19
Kalekale	8.3	11.8	6.9	9.7	1.04	2.94
Lehi	16.4	24.8	17.2	24.9	2.58	0.64
Onaga	48.8	126.1	33.9	88.5	5.09	9.66
Opakapaka	205.4	440.5	230.7	480.8	34.63	22.54
Uku	87.9	162.7	74.9	160.6	11.24	10.59
Ulua	94.4	121.4	158.9	144.8	12.86	17.74
Wekeula	20.8	30.2	18.4	27.7	2.76	9.22
Other						
Taape	60.4	32.4	59.4	31.3		
Akule	367.4	353.6	435.8	402.1		
Kahalalu	84.7	84.2	73.6	71.1		
Opelu	428.0	463.3	491.1	523.0		

Table 2-A. Bottom fish (management unit species). Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	895.2	406.0	384.11	551.09	1398.68
1950	994.6	451.1	359.75	537.75	1364.90
1951	927.7	420.7	358.39	504.77	1281.11
1952	1066.1	483.5	429.34	587.34	1490.66
1953	970.5	440.1	385.39	522.92	1327.16
1954	745.4	338.0	291.84	392.26	995.56
1955	791.3	358.8	322.02	427.09	1083.94
1956	645.5	292.8	293.70	384.43	975.68
1957	606.3	275.0	282.32	357.37	907.01
1958	597.7	271.1	273.82	330.70	839.31
1959	425.8	193.1	224.79	266.97	677.57
1960	489.6	222.0	257.45	275.14	698.31
1961	464.6	210.7	219.46	247.70	628.66
1962	509.7	231.2	250.08	276.03	700.55
1963	603.4	273.7	279.79	302.15	766.86
1964	590.1	267.6	277.07	298.24	756.94
1965	472.2	214.1	239.67	253.35	643.01
1966	508.8	230.8	253.65	260.69	661.62
1967	459.5	208.4	254.36	254.36	645.56
1968	453.8	205.8	268.92	259.07	657.53
1969	452.6	205.3	287.22	264.72	671.86
1970	381.0	172.8	254.69	223.02	566.03
1971	439.2	199.2	322.57	271.30	688.56
1972	435.6	197.5	377.46	307.37	780.12
1973	482.9	219.0	429.63	334.87	849.89
1974	434.6	197.1	431.79	304.29	772.29
1975	568.8	257.9	599.65	386.87	981.87
1976	561.7	254.8	702.72	431.64	1095.51
1977	577.3	261.8	779.63	453.80	1151.75
1978	722.7	327.8	1099.97	595.22	1510.67
AVERAGE	609.1	276.3	372.38	362.08	918.97

Table 2-B.--Bottom fish (management unit species). Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	45.0	20.4	29.37	28.33	71.91
FEBRUARY	53.3	24.2	32.71	31.85	80.83
MARCH	57.1	25.9	36.13	35.68	90.55
APRIL	52.8	23.9	31.58	31.43	79.76
MAY	53.8	24.4	30.37	29.82	75.69
JUNE	46.4	21.1	24.21	24.27	61.60
JULY	43.8	19.9	24.21	24.90	63.19
AUGUST	43.0	19.5	26.87	26.81	68.05
SEPTEMBER	49.5	22.4	29.33	28.79	73.07
OCTOBER	47.8	21.7	30.64	28.65	72.72
NOVEMBER	50.0	22.7	31.82	29.61	75.15
DECEMBER	66.6	30.2	45.13	41.94	106.44
AVERAGE	50.8	23.0	31.03	30.17	76.58

Table 3-A.--Ehu. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	58.7	26.6	41.29	59.23	150.34
1950	68.6	31.1	39.90	59.64	151.36
1951	48.8	22.2	29.73	41.88	106.29
1952	54.9	24.9	37.45	51.24	130.04
1953	46.2	21.0	33.49	45.44	115.32
1954	33.7	15.3	23.28	31.29	79.42
1955	39.2	17.8	27.60	36.60	92.90
1956	46.0	20.9	31.51	41.25	104.69
1957	32.4	14.7	25.13	31.81	80.73
1958	23.3	10.6	18.17	21.95	55.70
1959	19.8	9.0	17.06	20.26	51.43
1960	18.0	8.2	14.71	17.05	43.27
1961	12.8	5.8	11.17	12.61	32.00
1962	23.5	10.7	17.54	19.36	49.12
1963	28.1	12.7	21.54	23.26	59.03
1964	22.9	10.4	18.55	19.97	50.67
1965	19.9	9.0	15.00	15.86	40.24
1966	19.6	8.9	14.86	15.28	38.77
1967	16.0	7.3	13.64	13.64	34.61
1968	22.7	10.3	20.30	19.56	49.65
1969	16.6	7.5	18.58	17.12	43.45
1970	16.7	7.6	20.82	18.23	46.28
1971	21.9	9.9	27.79	23.37	59.32
1972	30.2	13.7	42.09	34.27	86.99
1973	22.0	10.0	31.65	24.67	62.60
1974	26.8	12.2	38.86	27.38	69.50
1975	29.3	13.3	48.22	31.11	78.95
1976	35.7	16.2	59.78	36.70	93.14
1977	31.7	14.4	61.58	35.84	90.97
1978	35.3	16.0	72.14	39.04	99.07
AVERAGE	30.7	13.9	29.78	29.50	74.86

Table 3-B.--Ehu. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	2.3	1.1	2.29	2.18	5.54
FEBRUARY	2.5	1.1	2.45	2.34	5.93
MARCH	2.8	1.3	2.82	2.82	7.17
APRIL	2.8	1.3	2.80	2.83	7.19
MAY	3.0	1.4	2.88	2.90	7.35
JUNE	2.4	1.1	2.17	2.20	5.58
JULY	2.5	1.1	2.30	2.39	6.07
AUGUST	2.3	1.0	2.20	2.24	5.67
SEPTEMBER	2.5	1.1	2.18	2.19	5.55
OCTOBER	2.1	1.0	1.94	1.93	4.89
NOVEMBER	2.1	1.0	2.01	1.94	4.92
DECEMBER	3.4	1.5	3.73	3.55	9.00
AVERAGE	2.6	1.2	2.48	2.46	6.24

Table 4-A.--Gindai. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	.	.	.	.	.
1950	.	.	.	.	.
1951	.	.	.	.	.
1952	.	.	.	.	.
1953	.	.	.	.	.
1954	.	.	.	.	.
1955	.	.	.	.	.
1956	.	.	.	.	.
1957	1.0	0.5	0.47	0.60	1.52
1958	2.1	0.9	0.96	1.16	2.94
1959	1.3	0.6	0.71	0.84	2.14
1960	1.1	0.5	0.53	0.61	1.56
1961	0.7	0.3	0.32	0.36	0.91
1962	0.9	0.4	0.42	0.46	1.17
1963	2.3	1.0	1.01	1.09	2.77
1964	1.5	0.7	0.74	0.80	2.03
1965	0.5	0.2	0.22	0.24	0.60
1966	1.0	0.5	0.45	0.47	1.18
1967	0.7	0.3	0.31	0.31	0.78
1968	0.8	0.3	0.45	0.44	1.11
1969	1.4	0.6	1.02	0.94	2.38
1970	1.7	0.8	1.30	1.14	2.88
1971	2.1	0.9	1.69	1.43	3.62
1972	1.9	0.9	1.74	1.42	3.59
1973	2.6	1.2	2.36	1.84	4.67
1974	1.5	0.7	1.52	1.07	2.72
1975	2.0	0.9	2.19	1.41	3.59
1976	1.5	0.7	1.62	0.99	2.52
1977	1.5	0.7	2.01	1.17	2.97
1978	3.6	1.6	5.81	3.14	7.98
AVERAGE	1.5	0.7	1.27	1.00	2.53

Table 4-B.--Gindai. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	0.1	0.1	0.11	0.08	0.21
FEBRUARY	0.1	0.1	0.11	0.08	0.21
MARCH	0.1	0.1	0.12	0.10	0.24
APRIL	0.1	0.1	0.10	0.08	0.21
MAY	0.1	0.1	0.12	0.09	0.23
JUNE	0.1	0.0	0.08	0.07	0.17
JULY	0.1	0.1	0.11	0.09	0.24
AUGUST	0.2	0.1	0.14	0.11	0.29
SEPTEMBER	0.2	0.1	0.14	0.11	0.27
OCTOBER	0.1	0.1	0.09	0.07	0.18
NOVEMBER	0.1	0.0	0.10	0.07	0.18
DECEMBER	0.2	0.1	0.13	0.10	0.26
AVERAGE	0.1	0.1	0.11	0.09	0.22

Table 5-A.--Hapuupuu. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	63.8	28.9	23.67	33.96	86.19
1950	84.3	38.2	22.43	33.53	85.10
1951	73.6	33.4	23.61	33.25	84.40
1952	91.9	41.7	31.41	42.97	109.05
1953	74.2	33.6	20.58	27.93	70.87
1954	40.0	18.2	11.98	16.11	40.88
1955	65.6	29.8	19.82	26.29	66.72
1956	41.6	18.9	15.23	19.93	50.58
1957	32.2	14.6	14.51	18.37	46.63
1958	28.6	13.0	11.82	14.28	36.23
1959	29.0	13.2	13.93	16.54	41.99
1960	22.4	10.1	11.22	13.00	32.99
1961	20.5	9.3	10.71	12.08	30.67
1962	22.3	10.1	9.72	10.73	27.23
1963	32.7	14.8	13.36	14.43	36.62
1964	24.1	10.9	9.81	10.56	26.79
1965	21.2	9.6	9.28	9.81	24.90
1966	33.1	15.0	14.17	14.56	36.96
1967	23.4	10.6	11.24	11.24	28.52
1968	21.0	9.5	12.35	11.90	30.20
1969	21.2	9.6	12.95	11.93	30.29
1970	40.5	18.4	25.22	22.09	56.06
1971	49.6	22.5	35.60	29.94	75.99
1972	36.9	16.7	31.06	25.29	64.19
1973	50.8	23.0	49.47	38.55	97.85
1974	39.4	17.9	38.73	27.30	69.28
1975	59.8	27.1	63.89	41.22	104.62
1976	58.4	26.5	72.62	44.61	113.22
1977	49.1	22.3	60.47	35.20	89.34
1978	74.5	33.8	100.49	54.38	138.01
AVERAGE	44.2	20.0	26.71	24.07	61.08

Table 5-B.--Hapuupuu. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	2.8	1.3	1.62	1.57	3.98
FEBRUARY	3.8	1.7	2.32	2.10	5.32
MARCH	3.9	1.7	2.64	2.35	5.96
APRIL	4.3	2.0	2.80	2.44	6.20
MAY	4.3	2.0	2.39	2.22	5.65
JUNE	3.3	1.5	1.71	1.59	4.02
JULY	3.1	1.4	1.93	1.75	4.44
AUGUST	3.4	1.5	2.16	1.94	4.93
SEPTEMBER	4.1	1.8	2.64	2.27	5.75
OCTOBER	3.0	1.4	1.76	1.59	4.03
NOVEMBER	3.7	1.7	2.13	1.93	4.89
DECEMBER	4.4	2.0	2.59	2.33	5.90
AVERAGE	3.7	1.7	2.23	2.01	5.09

Table 6-A.--Kahala. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	190.3	86.3	60.34	86.57	219.70
1950	168.9	76.6	37.13	55.50	140.85
1951	169.4	76.8	40.40	56.90	144.41
1952	156.1	70.8	34.70	47.47	120.49
1953	94.7	43.0	17.80	24.15	61.28
1954	68.0	30.8	12.70	17.07	43.33
1955	83.0	37.6	16.80	22.28	56.54
1956	54.6	24.8	12.43	16.27	41.30
1957	70.1	31.8	19.10	24.18	61.37
1958	89.5	40.6	22.68	27.39	69.51
1959	73.9	33.5	22.37	26.56	67.42
1960	86.4	39.2	25.30	29.32	74.41
1961	76.8	34.8	22.78	25.71	65.26
1962	85.3	38.7	26.49	29.24	74.20
1963	105.7	47.9	29.15	31.48	79.89
1964	95.6	43.4	27.51	29.62	75.17
1965	75.0	34.0	21.07	22.27	56.52
1966	99.1	44.9	28.61	29.40	74.62
1967	69.4	31.5	21.51	21.51	54.58
1968	85.2	38.6	28.97	27.91	70.83
1969	72.8	33.0	26.29	24.23	61.50
1970	70.1	31.8	25.69	22.50	57.10
1971	83.3	37.8	35.17	29.58	75.08
1972	57.0	25.8	26.25	21.38	54.26
1973	66.1	30.0	42.96	33.48	84.98
1974	34.1	15.5	16.92	11.92	30.26
1975	29.9	13.6	13.92	8.98	22.80
1976	41.0	18.6	21.63	13.29	33.72
1977	57.4	26.0	34.80	20.26	51.41
1978	99.1	44.9	71.39	38.63	98.04
AVERAGE	86.9	39.4	28.10	29.17	74.03

Table 6-B.--Kahala. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	7.4	3.3	2.68	2.87	7.28
FEBRUARY	11.0	5.0	3.62	3.77	9.57
MARCH	14.6	6.6	5.72	5.82	14.78
APRIL	11.7	5.3	3.68	3.90	9.90
MAY	6.9	3.1	1.88	1.96	4.97
JUNE	3.9	1.8	0.96	1.02	2.59
JULY	3.7	1.7	0.94	1.02	2.59
AUGUST	3.5	1.6	1.05	1.15	2.92
SEPTEMBER	4.8	2.2	1.41	1.50	3.82
OCTOBER	4.5	2.0	1.44	1.44	3.64
NOVEMBER	5.9	2.7	1.73	1.77	4.50
DECEMBER	9.1	4.1	2.98	2.94	7.46
AVERAGE	7.2	3.3	2.34	2.43	6.17

Table 7-A.--Kalekale. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	29.7	13.5	17.00	24.40	61.92
1950	31.9	14.5	14.27	21.33	54.13
1951	42.8	19.4	17.89	25.20	63.96
1952	32.0	14.5	17.07	23.36	59.28
1953	38.8	17.6	19.29	26.17	66.43
1954	32.4	14.7	14.02	18.85	47.84
1955	33.8	15.3	15.80	20.95	53.17
1956	32.6	14.8	14.62	19.14	48.58
1957	20.6	9.4	9.93	12.57	31.91
1958	19.2	8.7	9.75	11.78	29.90
1959	20.9	9.5	11.55	13.72	34.83
1960	16.3	7.4	9.21	10.67	27.08
1961	19.0	8.6	9.63	10.87	27.58
1962	18.3	8.3	9.46	10.45	26.51
1963	24.3	11.0	11.76	12.71	32.25
1964	15.7	7.1	8.46	9.11	23.12
1965	14.0	6.4	7.84	8.29	21.03
1966	13.1	5.9	7.31	7.51	19.07
1967	7.0	3.2	4.01	4.01	10.17
1968	5.1	2.3	3.47	3.34	8.48
1969	5.6	2.6	5.54	5.10	12.95
1970	4.5	2.0	4.96	4.34	11.02
1971	7.0	3.2	7.23	6.08	15.43
1972	7.1	3.2	8.46	6.89	17.48
1973	6.5	2.9	6.43	5.01	12.72
1974	5.8	2.6	6.85	4.83	12.25
1975	8.9	4.0	11.33	7.31	18.56
1976	9.2	4.2	12.83	7.88	20.00
1977	7.3	3.3	9.70	5.65	14.34
1978	9.8	4.4	17.46	9.45	23.98
AVERAGE	18.0	8.2	10.77	11.90	30.20

Table 7-B.--Kalekale. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	1.2	0.6	0.77	0.83	2.11
FEBRUARY	1.4	0.6	0.88	0.95	2.42
MARCH	1.5	0.7	0.99	1.10	2.78
APRIL	1.6	0.7	0.97	1.12	2.83
MAY	1.3	0.6	0.78	0.87	2.21
JUNE	0.8	0.4	0.55	0.62	1.58
JULY	1.4	0.6	0.79	0.91	2.30
AUGUST	1.5	0.7	0.92	1.01	2.55
SEPTEMBER	1.5	0.7	0.83	0.91	2.31
OCTOBER	1.7	0.8	0.93	1.02	2.58
NOVEMBER	1.7	0.8	0.98	1.06	2.70
DECEMBER	2.3	1.0	1.38	1.51	3.83
AVERAGE	1.5	0.7	0.90	0.99	2.52

Table 8-A.--Lehi. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	•	•	•	•	•
1950	•	•	•	•	•
1951	•	•	•	•	•
1952	•	•	•	•	•
1953	•	•	•	•	•
1954	•	•	•	•	•
1955	•	•	•	•	•
1956	•	•	•	•	•
1957	0.6	0.3	0.28	0.35	0.89
1958	3.4	1.5	1.15	1.39	3.52
1959	1.1	0.5	0.46	0.55	1.40
1960	1.2	0.5	0.48	0.56	1.42
1961	1.5	0.7	0.50	0.57	1.44
1962	2.0	0.9	0.70	0.77	1.96
1963	2.3	1.0	0.76	0.82	2.09
1964	1.0	0.4	0.38	0.41	1.03
1965	1.4	0.6	0.56	0.59	1.49
1966	2.4	1.1	0.88	0.91	2.30
1967	2.6	1.2	0.93	0.93	2.36
1968	3.9	1.8	1.52	1.46	3.72
1969	4.7	2.1	1.98	1.83	4.64
1970	1.3	0.6	0.63	0.55	1.41
1971	2.1	1.0	1.23	1.03	2.62
1972	5.1	2.3	3.18	2.59	6.58
1973	6.6	2.9	4.32	3.37	8.55
1974	4.3	1.9	3.23	2.27	5.77
1975	10.5	4.8	8.75	5.65	14.33
1976	9.5	4.3	8.36	5.14	13.03
1977	8.8	4.0	8.58	5.00	12.68
1978	10.2	4.6	13.58	7.35	18.66
AVERAGE	3.9	1.8	2.54	2.00	5.09

Table 8-B.--Lehi. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	0.5	0.2	0.30	0.22	0.56
FEBRUARY	0.4	0.2	0.29	0.21	0.53
MARCH	0.5	0.2	0.31	0.23	0.59
APRIL	0.3	0.1	0.21	0.15	0.39
MAY	0.3	0.1	0.19	0.13	0.34
JUNE	0.1	0.1	0.08	0.06	0.14
JULY	0.1	0.0	0.05	0.04	0.10
AUGUST	0.1	0.1	0.09	0.07	0.17
SEPTEMBER	0.2	0.1	0.12	0.09	0.24
OCTOBER	0.3	0.2	0.29	0.19	0.48
NOVEMBER	0.6	0.3	0.49	0.32	0.82
DECEMBER	0.7	0.3	0.56	0.39	0.99
AVERAGE	0.3	0.2	0.25	0.18	0.45

Table 9-A.--Onaga. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	.	.	.	.	.
1950	88.0	39.9	48.96	73.19	185.76
1951	56.7	25.7	37.02	52.14	132.34
1952	43.1	19.5	31.03	42.45	107.75
1953	58.3	26.4	43.51	59.04	149.85
1954	71.2	32.3	48.98	65.83	167.07
1955	64.5	29.2	46.93	62.24	157.97
1956	85.9	38.9	59.39	77.73	197.29
1957	62.0	28.1	42.37	54.27	137.74
1958	65.9	29.9	49.78	60.12	152.59
1959	46.3	21.0	41.75	49.58	125.85
1960	40.9	18.5	35.92	41.62	105.63
1961	43.0	19.5	37.63	42.47	107.79
1962	62.4	28.3	56.14	61.97	157.27
1963	53.9	24.5	49.83	53.81	136.56
1964	57.4	26.0	52.74	56.77	144.08
1965	65.9	29.9	62.68	66.26	168.17
1966	69.7	31.6	68.83	70.74	179.54
1967	58.1	26.4	61.69	61.69	156.58
1968	69.9	31.7	76.87	74.06	187.95
1969	48.5	22.0	68.59	63.22	160.46
1970	38.2	17.3	59.88	52.43	133.08
1971	48.0	21.7	70.94	59.66	151.42
1972	50.3	22.8	84.73	69.00	175.12
1973	42.7	19.4	70.80	55.18	140.06
1974	40.5	18.4	77.65	54.73	138.89
1975	66.2	30.0	119.64	77.19	195.90
1976	90.6	41.1	201.20	123.59	313.66
1977	67.3	30.5	165.30	96.22	244.20
1978	62.4	28.3	165.49	89.55	227.29
AVERAGE	59.2	26.9	70.23	64.37	163.37

Table 9-B.--Onaga. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	4.7	2.1	5.90	5.02	12.74
FEBRUARY	5.3	2.4	6.37	5.62	14.27
MARCH	4.8	2.2	5.79	5.42	13.75
APRIL	4.2	1.9	5.05	4.69	11.90
MAY	4.1	1.9	4.90	4.44	11.28
JUNE	2.6	1.2	3.32	3.00	7.62
JULY	3.2	1.5	3.81	3.67	9.31
AUGUST	4.9	2.2	5.62	5.37	13.62
SEPTEMBER	5.6	2.5	5.95	5.76	14.61
OCTOBER	6.3	2.9	7.11	6.61	16.78
NOVEMBER	5.7	2.6	6.33	5.83	14.79
DECEMBER	7.7	3.5	10.07	8.95	22.71
AVERAGE	4.9	2.2	5.85	5.36	13.61

Table 10-A.--Opakapaka. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	225.6	102.3	96.20	138.02	350.28
1950	238.5	108.2	83.11	124.23	315.30
1951	272.4	123.5	105.54	148.65	377.28
1952	300.3	136.2	120.32	164.60	417.75
1953	214.8	97.4	87.38	118.57	300.92
1954	143.1	64.9	57.26	76.97	195.34
1955	181.3	82.2	78.10	103.53	262.87
1956	148.8	67.5	61.09	79.96	202.93
1957	127.0	57.6	57.49	72.78	184.71
1958	121.6	55.1	56.84	68.65	174.24
1959	78.6	35.6	41.04	48.74	123.70
1960	88.5	40.1	46.14	53.47	135.70
1961	93.4	42.4	44.29	49.99	126.88
1962	103.0	46.7	50.39	55.61	141.15
1963	121.1	54.9	57.25	61.82	156.91
1964	105.6	47.9	51.08	54.98	139.54
1965	83.4	37.8	42.66	45.10	114.46
1966	97.5	44.2	47.93	49.26	125.02
1967	110.1	50.0	58.00	58.00	147.21
1968	89.8	40.7	49.41	47.60	120.81
1969	90.0	40.8	59.90	55.20	140.11
1970	52.8	24.0	39.59	34.66	87.98
1971	82.4	37.4	67.34	56.64	143.75
1972	118.1	53.6	100.31	81.69	207.32
1973	132.1	59.9	115.02	89.65	227.53
1974	111.4	50.5	115.70	81.54	206.94
1975	161.0	73.0	174.02	112.27	284.94
1976	121.8	55.3	155.58	95.57	242.55
1977	150.9	68.4	226.67	131.94	334.85
1978	176.6	80.1	343.62	185.94	471.92
AVERAGE	138.1	62.6	89.64	84.86	215.36

Table 10-B.--Opakapaka. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	13.6	6.2	8.96	8.49	21.55
FEBRUARY	14.6	6.6	9.46	9.00	22.84
MARCH	15.0	6.8	10.07	9.93	25.20
APRIL	11.2	5.1	7.36	7.32	18.57
MAY	9.3	4.2	5.66	5.53	14.04
JUNE	7.0	3.2	4.16	4.06	10.31
JULY	7.0	3.2	3.92	4.08	10.35
AUGUST	7.1	3.2	4.63	4.54	11.52
SEPTEMBER	10.2	4.6	6.15	5.95	15.10
OCTOBER	11.0	5.0	7.68	6.64	16.86
NOVEMBER	12.8	5.8	8.76	7.70	19.54
DECEMBER	19.1	8.7	12.83	11.62	29.49
AVERAGE	11.5	5.2	7.47	7.07	17.95

Table 11-A.--Uku. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	71.6	32.5	30.58	43.87	111.34
1950	71.4	32.4	26.71	39.92	101.32
1951	53.2	24.1	19.22	27.06	68.69
1952	66.9	30.4	26.09	35.69	90.57
1953	73.5	33.3	29.76	40.38	102.49
1954	65.6	29.8	23.80	31.99	81.19
1955	82.1	37.3	28.24	37.46	95.07
1956	81.6	37.0	33.45	43.78	111.11
1957	101.0	45.8	40.13	50.79	128.91
1958	74.3	33.7	31.03	37.47	95.11
1959	36.3	16.5	18.22	21.64	54.92
1960	46.0	20.9	20.93	24.25	61.55
1961	42.3	19.2	17.91	20.21	51.30
1962	64.8	29.4	25.94	28.64	72.68
1963	65.1	29.5	27.92	30.15	76.52
1964	89.8	40.7	36.31	39.09	99.21
1965	50.4	22.9	21.46	22.69	57.59
1966	58.1	26.4	23.90	24.56	62.34
1967	58.6	26.6	26.55	26.55	67.38
1968	49.4	22.4	24.29	23.40	59.39
1969	57.8	26.2	29.50	27.19	69.00
1970	49.3	22.3	28.39	24.86	63.11
1971	49.0	22.2	29.69	24.97	63.38
1972	52.2	23.7	34.90	28.42	72.13
1973	69.2	31.4	48.94	38.14	96.81
1974	82.6	37.5	71.32	50.26	127.57
1975	62.3	28.3	62.16	40.10	101.78
1976	63.4	28.7	66.26	40.70	103.30
1977	72.5	32.9	99.65	58.00	147.21
1978	85.8	38.9	139.01	75.22	190.91
AVERAGE	64.9	29.4	38.08	35.25	89.46

Table 11-B.--Uku. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	2.4	1.1	1.60	1.49	3.78
FEBRUARY	2.5	1.2	1.65	1.51	3.82
MARCH	2.5	1.1	1.82	1.63	4.13
APRIL	3.0	1.4	2.13	1.89	4.79
MAY	8.5	3.8	4.84	4.31	10.93
JUNE	12.0	5.4	5.44	5.38	13.64
JULY	8.7	3.9	4.49	4.49	11.39
AUGUST	6.8	3.1	4.14	3.92	9.95
SEPTEMBER	5.0	2.3	2.99	2.73	6.92
OCTOBER	4.5	2.0	2.84	2.53	6.43
NOVEMBER	4.2	1.9	2.79	2.46	6.24
DECEMBER	4.8	2.2	3.36	2.93	7.43
AVERAGE	5.4	2.5	3.17	2.94	7.46

Table 12-A.--Ulua. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	193.6	87.8	77.45	111.11	282.01
1950	182.5	82.8	56.12	83.89	212.91
1951	156.8	71.1	55.13	77.72	197.25
1952	231.1	104.8	84.04	114.96	291.77
1953	297.1	134.7	94.53	128.20	325.53
1954	215.4	97.7	62.61	84.16	213.60
1955	170.3	77.2	53.74	71.27	180.89
1956	92.1	41.8	34.91	45.70	115.97
1957	96.3	43.7	39.83	50.42	127.96
1958	85.6	38.8	32.61	39.38	99.95
1959	48.9	22.2	21.81	25.90	65.74
1960	93.2	42.3	39.92	46.25	117.39
1961	68.9	31.3	29.87	33.71	85.55
1962	69.0	31.3	30.22	33.36	84.66
1963	87.2	39.6	33.86	36.57	92.81
1964	107.9	48.9	42.69	45.96	116.64
1965	74.6	33.8	33.24	35.14	89.18
1966	64.2	29.1	29.13	29.93	75.97
1967	77.2	35.0	43.12	43.12	109.43
1968	79.1	35.9	41.28	39.77	100.95
1969	95.6	43.3	48.29	44.51	112.97
1970	64.4	29.2	33.07	28.96	73.50
1971	60.7	27.5	32.96	27.72	70.36
1972	43.3	19.6	30.52	24.85	63.07
1973	47.7	21.6	41.57	32.40	82.24
1974	59.4	26.9	46.28	32.62	82.78
1975	101.9	46.2	74.97	48.37	122.76
1976	97.2	44.1	79.93	49.09	124.60
1977	77.4	35.1	73.44	42.75	108.49
1978	121.5	55.1	138.22	74.80	189.83
AVERAGE	108.7	49.3	51.18	52.75	133.89

Table 12-B.--Ulua. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	6.0	2.7	3.22	3.33	8.45
FEBRUARY	7.4	3.4	3.62	4.00	10.16
MARCH	7.0	3.2	3.74	3.91	9.92
APRIL	7.9	3.6	3.92	4.04	10.25
MAY	10.3	4.7	4.40	4.70	11.93
JUNE	9.7	4.4	3.94	4.19	10.62
JULY	10.2	4.6	4.16	4.49	11.39
AUGUST	9.4	4.2	4.20	4.51	11.45
SEPTEMBER	11.3	5.1	5.04	5.21	13.22
OCTOBER	10.1	4.6	4.79	4.64	11.78
NOVEMBER	9.1	4.1	4.74	4.51	11.45
DECEMBER	10.4	4.7	5.43	5.23	13.28
AVERAGE	9.1	4.1	4.27	4.40	11.16

Table 13-A.--Weke. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	61.7	28.0	37.60	53.94	136.90
1950	60.6	27.5	31.12	46.52	118.07
1951	54.0	24.5	29.79	41.96	106.49
1952	89.7	40.7	47.22	64.60	163.96
1953	72.9	33.1	39.05	52.99	134.48
1954	76.0	34.4	37.20	50.00	126.89
1955	71.5	32.4	35.00	46.42	117.81
1956	62.4	28.3	31.08	40.68	103.24
1957	62.9	28.5	32.57	41.23	104.64
1958	84.3	38.2	39.02	47.13	119.62
1959	69.8	31.7	35.89	42.62	108.18
1960	75.7	34.3	33.09	38.34	97.32
1961	85.6	38.8	34.66	39.12	99.28
1962	58.2	26.4	23.05	25.45	64.58
1963	80.7	36.6	33.35	36.02	91.41
1964	68.5	31.1	28.79	30.99	78.65
1965	65.9	29.9	25.65	27.11	68.81
1966	51.1	23.2	17.57	18.05	45.84
1967	36.3	16.5	13.37	13.47	33.93
1968	27.0	12.2	9.99	9.63	24.44
1969	38.4	17.4	14.58	17.44	34.11
1970	41.5	18.8	15.13	13.25	33.62
1971	33.2	15.1	12.42	10.87	27.58
1972	33.4	15.1	14.22	11.58	29.39
1973	36.8	16.7	15.11	12.56	31.87
1974	28.7	13.0	14.72	10.38	26.33
1975	36.9	16.7	20.55	13.26	33.64
1976	33.4	15.1	22.94	14.09	35.76
1977	53.3	24.2	37.42	21.78	55.28
1978	43.9	19.9	32.75	17.72	44.98
AVERAGE	56.5	25.6	27.21	30.17	76.57

Table 13-B.--Weke. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	4.4	2.0	2.25	2.51	6.36
FEBRUARY	4.5	2.0	2.26	2.55	6.47
MARCH	4.8	2.2	2.42	2.65	6.73
APRIL	5.8	2.6	2.83	3.20	8.12
MAY	5.9	2.7	2.59	2.89	7.34
JUNE	4.7	2.1	1.98	2.25	5.70
JULY	4.1	1.9	1.90	2.15	5.45
AUGUST	4.1	1.8	1.98	2.20	5.58
SEPTEMBER	4.5	2.0	2.14	2.33	5.91
OCTOBER	4.4	2.0	2.11	2.29	5.81
NOVEMBER	4.4	2.0	2.17	2.34	5.93
DECEMBER	5.0	2.3	2.59	2.83	7.18
AVERAGE	4.7	2.1	2.27	2.51	6.33

Table 14-A.--Taape. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	.	.	.	.	.
1950	.	.	.	.	.
1951	.	.	.	.	.
1952	.	.	.	.	.
1953	.	.	.	.	.
1954	.	.	.	.	.
1955	.	.	.	.	.
1956	.	.	.	.	.
1957	.	.	.	.	.
1958	.	.	.	.	.
1959	.	.	.	.	.
1960	.	.	.	.	.
1961	.	.	.	.	.
1962	.	.	.	.	.
1963	.	.	.	.	.
1964	.	.	.	.	.
1965	.	.	.	.	.
1966	.	.	.	.	.
1967	.	.	.	.	.
1968	.	.	.	.	.
1969	.	.	.	.	.
1970	.	.	.	.	.
1971	.	.	.	.	.
1972	.	.	.	.	.
1973	.	.	.	.	.
1974	.	.	.	.	.
1975	17.5	7.9	6.79	4.38	11.12
1976	29.5	13.4	12.44	7.64	19.39
1977	36.1	16.4	19.70	11.47	29.11
1978	59.1	26.8	30.72	16.62	42.19
AVERAGE	35.5	16.1	17.41	10.03	25.45

Table 14-B.--Taape. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	3.0	1.4	1.60	0.91	2.30
FEBRUARY	4.7	2.1	2.40	1.36	3.46
MARCH	4.9	2.2	2.02	1.16	2.94
APRIL	2.2	1.0	1.12	0.65	1.65
MAY	2.1	1.0	1.03	0.58	1.48
JUNE	1.9	0.9	0.77	0.45	1.14
JULY	1.8	0.8	0.74	0.43	1.09
AUGUST	2.4	1.1	1.12	0.65	1.64
SEPTEMBER	3.1	1.4	1.62	0.93	2.35
OCTOBER	5.1	2.3	2.40	1.40	3.56
NOVEMBER	4.0	1.8	2.32	1.33	3.38
DECEMBER	3.5	1.6	1.77	1.04	2.64
AVERAGE	3.2	1.4	1.55	0.89	2.26

Table 15-A.--Akule. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	501.1	227.3	309.72	444.36	1127.79
1950	401.5	182.1	232.87	348.09	883.44
1951	440.2	199.6	262.95	370.35	939.96
1952	371.7	168.6	226.72	310.16	787.18
1953	314.5	142.6	201.93	273.86	695.05
1954	323.7	146.8	204.82	275.30	698.71
1955	304.4	138.0	191.75	254.31	645.44
1956	154.8	70.2	121.19	158.63	402.61
1957	177.4	80.4	127.76	161.77	410.44
1958	178.6	81.0	123.34	148.60	377.07
1959	147.8	67.0	118.18	140.38	356.23
1960	298.4	135.4	207.00	239.86	608.77
1961	168.6	76.5	110.61	124.85	316.86
1962	177.5	80.5	127.36	140.58	356.78
1963	128.6	58.3	95.92	103.59	262.90
1964	99.1	44.9	74.97	80.70	204.80
1965	238.8	108.3	153.47	162.23	411.74
1966	397.0	180.1	205.51	211.21	536.05
1967	588.5	266.9	245.90	245.90	624.09
1968	751.1	340.6	265.36	255.65	648.83
1969	408.6	185.3	164.53	151.64	384.86
1970	720.1	326.6	256.07	224.23	569.10
1971	544.9	247.1	227.47	191.31	485.55
1972	524.1	237.7	231.13	188.21	477.69
1973	643.4	291.8	294.80	237.67	602.95
1974	542.6	246.2	305.57	187.15	474.99
1975	434.3	196.9	247.99	159.99	406.07
1976	904.5	410.2	326.68	323.60	821.09
1977	659.4	299.1	483.86	281.64	714.81
1978	367.3	166.6	321.11	173.76	441.00
AVERAGE	397.1	180.1	221.22	213.94	555.79

Table 15-B.--Akule. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	25.4	11.5	15.89	15.68	39.80
FEBRUARY	30.0	13.6	18.60	17.98	45.63
MARCH	42.0	19.1	25.31	24.61	62.45
APRIL	46.7	21.2	26.05	24.34	61.79
MAY	53.4	24.2	26.23	25.19	63.94
JUNE	45.3	20.5	22.57	22.32	56.66
JULY	39.6	17.9	19.74	19.93	50.58
AUGUST	31.7	14.4	17.21	16.69	42.37
SEPTEMBER	25.5	11.6	14.65	15.09	38.30
OCTOBER	20.1	9.1	12.27	13.26	33.65
NOVEMBER	19.3	8.8	11.54	12.68	32.19
DECEMBER	23.3	10.6	14.15	14.27	36.22
AVERAGE	33.7	15.3	18.75	18.56	47.10

Table 16-A.--Hahalalu. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	.	.	.	.	.
1950	.	.	.	.	.
1951	.	.	.	.	.
1952	.	.	.	.	.
1953	.	.	.	.	.
1954	.	.	.	.	.
1955	.	.	.	.	.
1956	.	.	.	.	.
1957	.	.	.	.	.
1958	.	.	.	.	.
1959	.	.	.	.	.
1960	.	.	.	.	.
1961	.	.	.	.	.
1962	41.7	18.9	24.98	27.57	69.97
1963	22.1	10.0	16.26	17.56	44.58
1964	61.6	28.0	42.40	45.65	115.85
1965	210.8	95.6	85.80	90.69	230.19
1966	227.5	103.2	80.02	82.24	208.73
1967	264.8	120.1	82.12	82.12	208.43
1968	194.5	88.2	74.15	71.43	181.30
1969	390.4	177.1	152.25	140.32	356.14
1970	260.0	117.9	102.22	89.51	227.19
1971	274.0	124.3	116.64	98.10	248.98
1972	345.3	156.6	159.26	129.69	329.15
1973	137.2	62.2	63.41	49.42	125.44
1974	83.8	38.0	56.73	39.98	101.46
1975	76.7	34.8	59.02	38.08	96.64
1976	70.7	32.0	51.49	31.80	80.71
1977	61.9	28.1	57.47	33.45	84.89
1978	48.0	21.8	67.61	36.59	92.85
AVERAGE	173.0	78.5	75.93	72.24	184.32

Table 16-B.--Hahalalu. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	12.6	5.7	6.63	5.82	14.76
FEBRUARY	13.8	6.3	7.22	5.34	14.21
MARCH	12.1	5.5	6.52	5.42	13.75
APRIL	8.9	4.0	5.89	4.68	11.87
MAY	8.8	4.0	4.22	3.40	8.62
JUNE	9.3	4.2	4.05	3.23	8.21
JULY	4.6	2.1	2.74	2.20	5.57
AUGUST	15.2	6.9	5.85	5.51	13.98
SEPTEMBER	16.6	7.5	6.08	5.71	14.50
OCTOBER	14.4	6.5	5.98	5.66	14.33
NOVEMBER	31.8	14.4	13.03	10.87	27.59
DECEMBER	15.6	7.1	8.02	6.80	17.26
AVERAGE	13.7	6.2	6.36	5.44	13.80

Table 17-A.--Opelu. Annual catch and revenues, 1949-78.

YEAR	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
1949	244.5	110.9	102.23	146.[illegible]3	372.27
1950	181.1	82.1	71.57	106.98	271.51
1951	194.1	88.0	76.99	108.44	275.21
1952	245.7	111.4	89.73	122.75	311.55
1953	248.7	112.8	92.98	126.17	320.21
1954	274.4	124.4	87.8[illegible]	118.[illegible]9	299.71
1955	287.9	130.6	98.16	130.19	330.42
1956	311.6	141.3	97.41	127.50	323.59
1957	216.2	98.0	82.44	104.[illegible]6	264.86
1958	187.9	85.2	79.15	95.59	242.61
1959	188.8	85.6	74.73	88.75	225.25
1960	192.5	87.3	81.99	95.01	241.12
1961	209.0	94.8	84.27	95.11	241.39
1962	383.8	174.1	124.52	137.44	348.82
1963	401.1	181.9	129.38	139.72	354.61
1964	292.3	132.5	103.55	111.47	282.91
1965	190.0	86.2	74.98	79.26	201.15
1966	219.8	99.7	87.50	89.92	228.23
1967	211.4	95.9	85.51	85.51	217.02
1968	244.0	110.7	96.11	92.6[illegible]	235.01
1969	215.4	97.7	104.15	95.99	243.63
1970	174.1	79.0	97.84	85.65	217.45
1971	229.8	104.2	127.98	116.04	294.52
1972	171.7	77.9	117.22	95.46	242.27
1973	207.9	94.3	140.60	109.5[illegible]	278.13
1974	217.1	98.5	161.07	113.51	288.10
1975	320.6	145.4	244.72	157.88	400.71
1976	307.0	139.2	250.17	153.67	390.00
1977	396.9	180.0	347.31	202.1[illegible]	513.0[illegible]
1978	298.6	135.4	331.18	179.21	454.83
AVERAGE	248.8	112.8	125.11	117.22	297.01

Table 17-B.--Opelu. Monthly catch and revenues, 1949-78.

MONTH	CATCH IN THOUSANDS OF POUNDS	CATCH IN METRIC TONS	REVENUE IN THOUSANDS OF DOLLARS	DEFLATED REVENUE IN THOUSANDS OF DOLLARS	ADJUSTED REVENUE IN THOUSANDS OF DOLLARS
JANUARY	15.7	7.1	8.27	7.89	20.04
FEBRUARY	14.1	6.4	7.56	7.32	18.58
MARCH	13.9	6.3	7.84	7.56	19.19
APRIL	14.4	6.5	7.97	7.74	19.65
MAY	12.9	5.9	7.14	6.63	16.84
JUNE	11.2	5.1	6.18	5.64	14.32
JULY	14.2	6.4	8.03	7.44	18.89
AUGUST	20.8	9.5	11.23	10.38	26.34
SEPTEMBER	35.5	16.1	17.04	15.63	39.68
OCTOBER	38.3	17.4	16.30	15.48	39.30
NOVEMBER	31.0	14.0	14.51	13.34	33.85
DECEMBER	26.7	12.1	13.03	11.95	30.33
AVERAGE	20.7	9.4	10.43	9.79	24.75

Figure 1-A.--Bottom fish (management unit species). Annual catch and revenues, 1949-78.

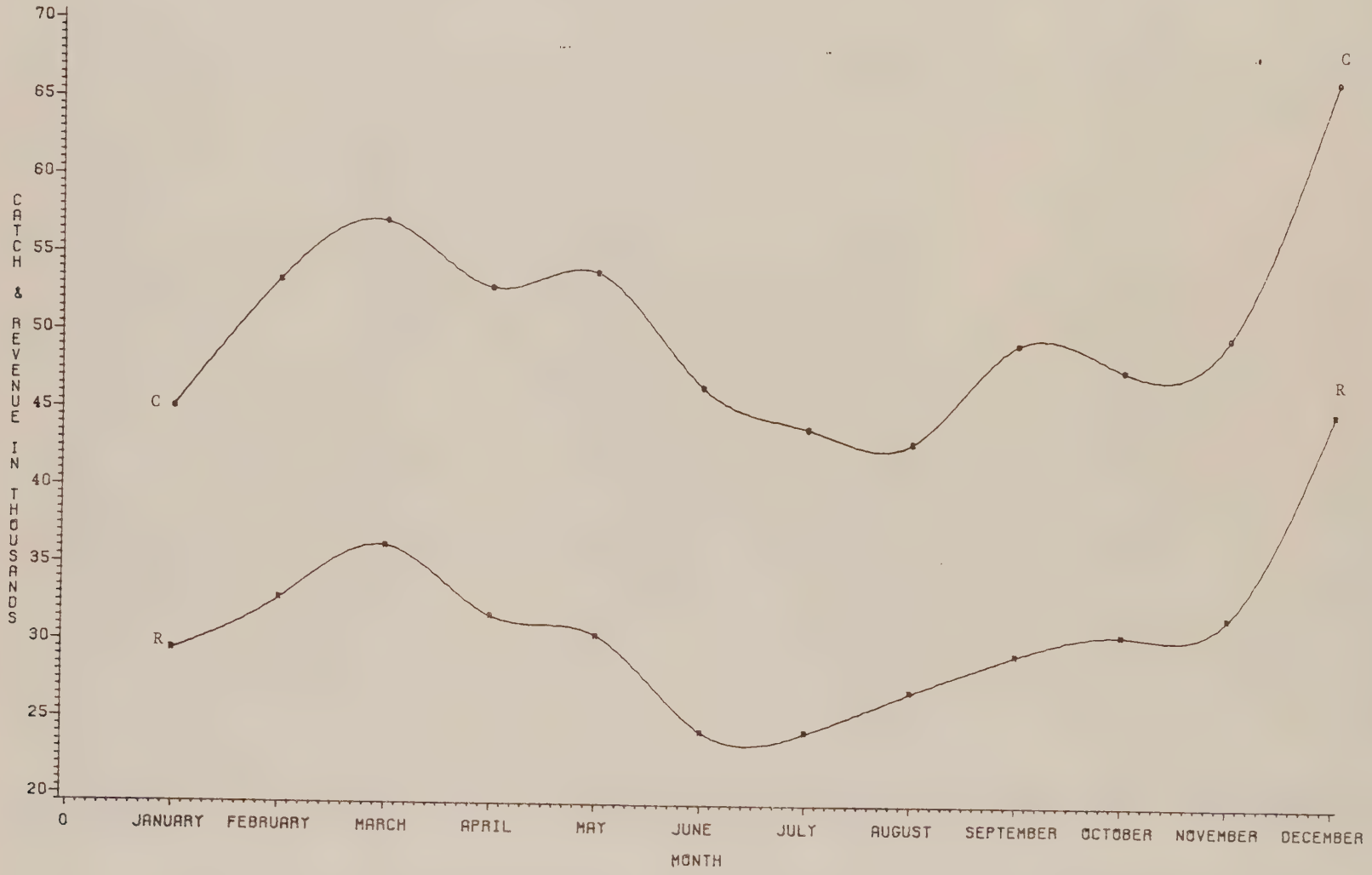

Figure 1-B.--Bottom fish (management unit species). Monthly catch and revenues, 1949-78.

Figure 2-A.--Ehu. Annual catch and revenues, 1949-78.

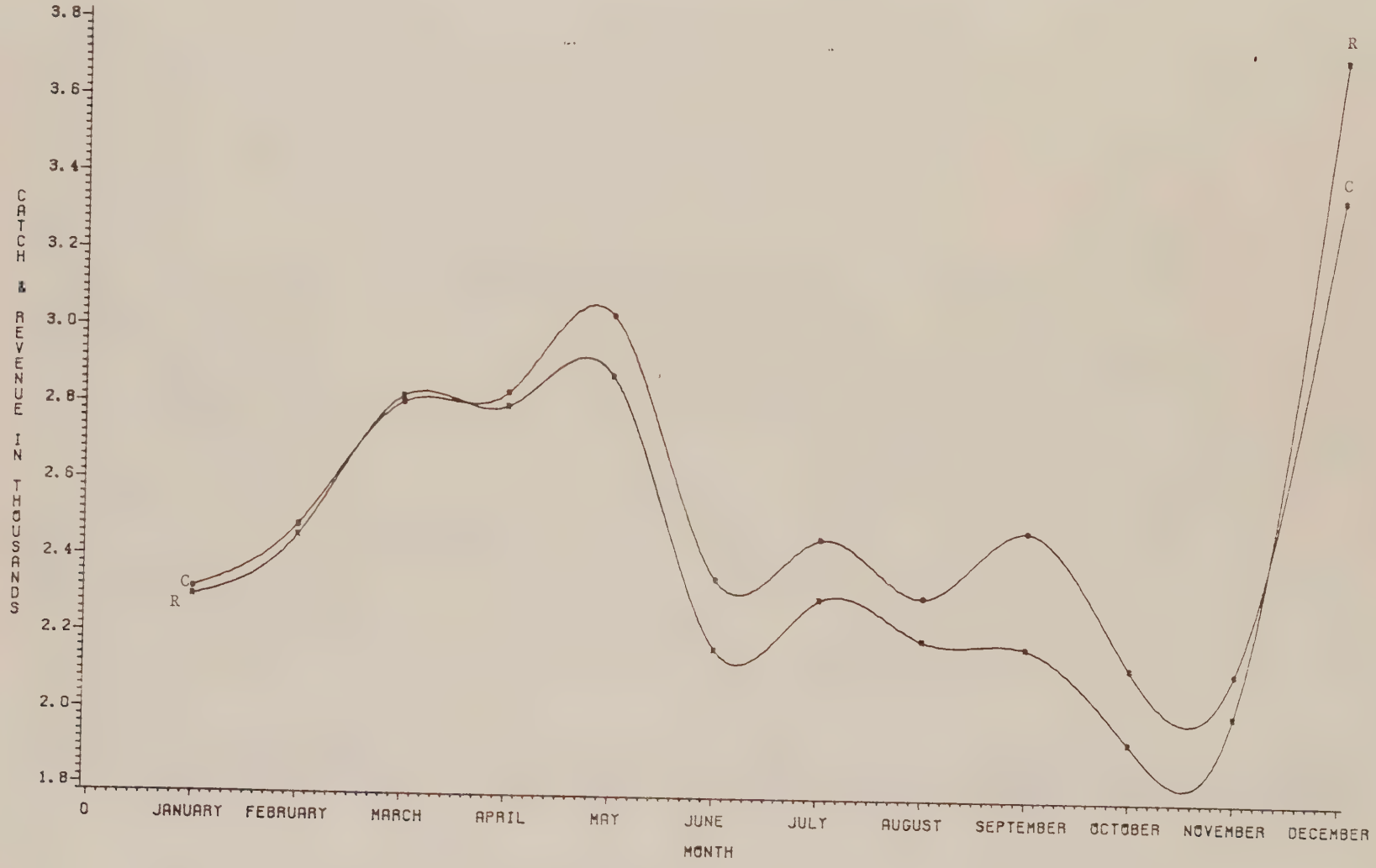

Figure 2-B.--Ehu. Monthly catch and revenues from 1949-78.

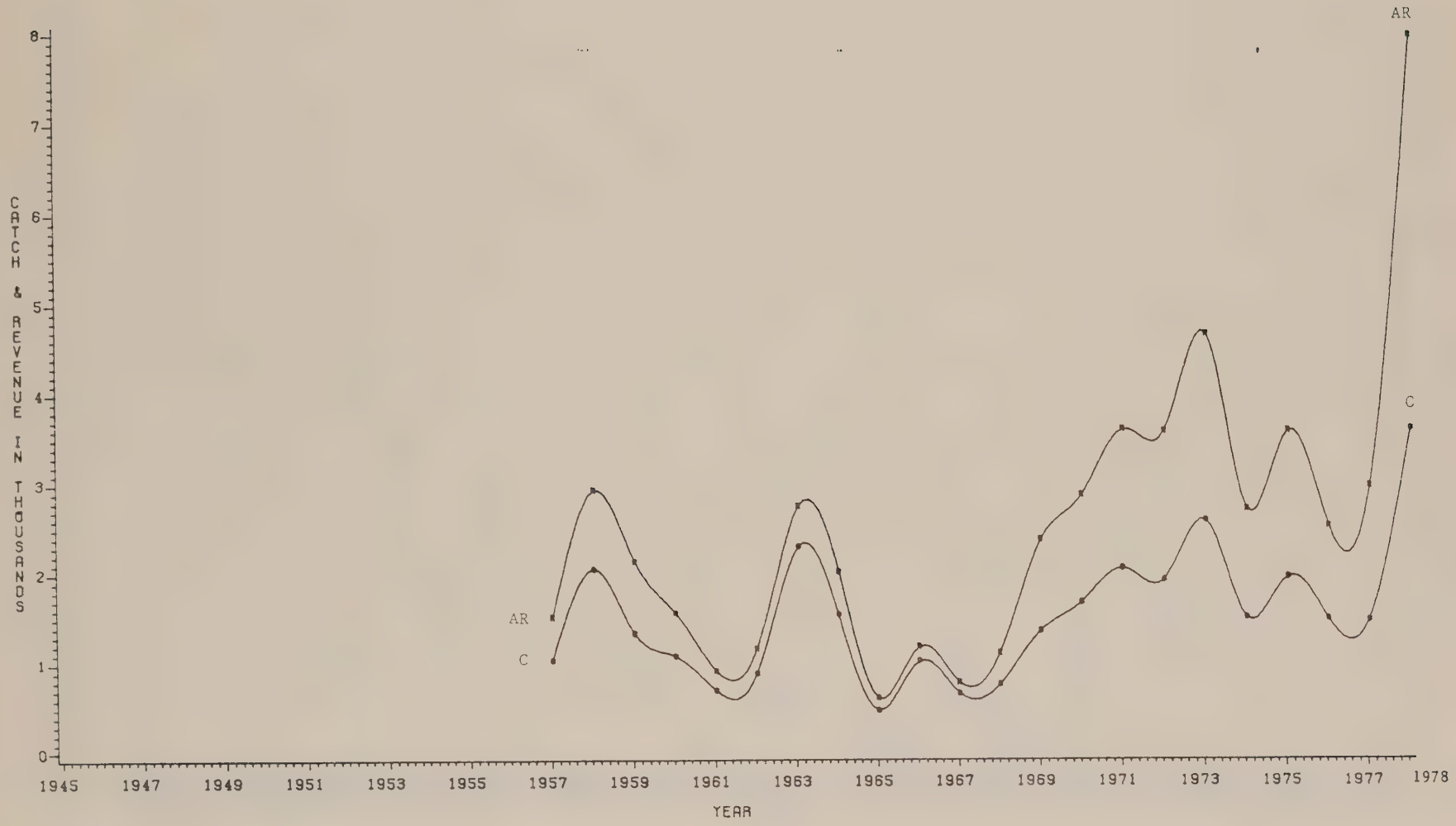

Figure 3-A.--Gindai. Annual catch and revenues, 1949-78.

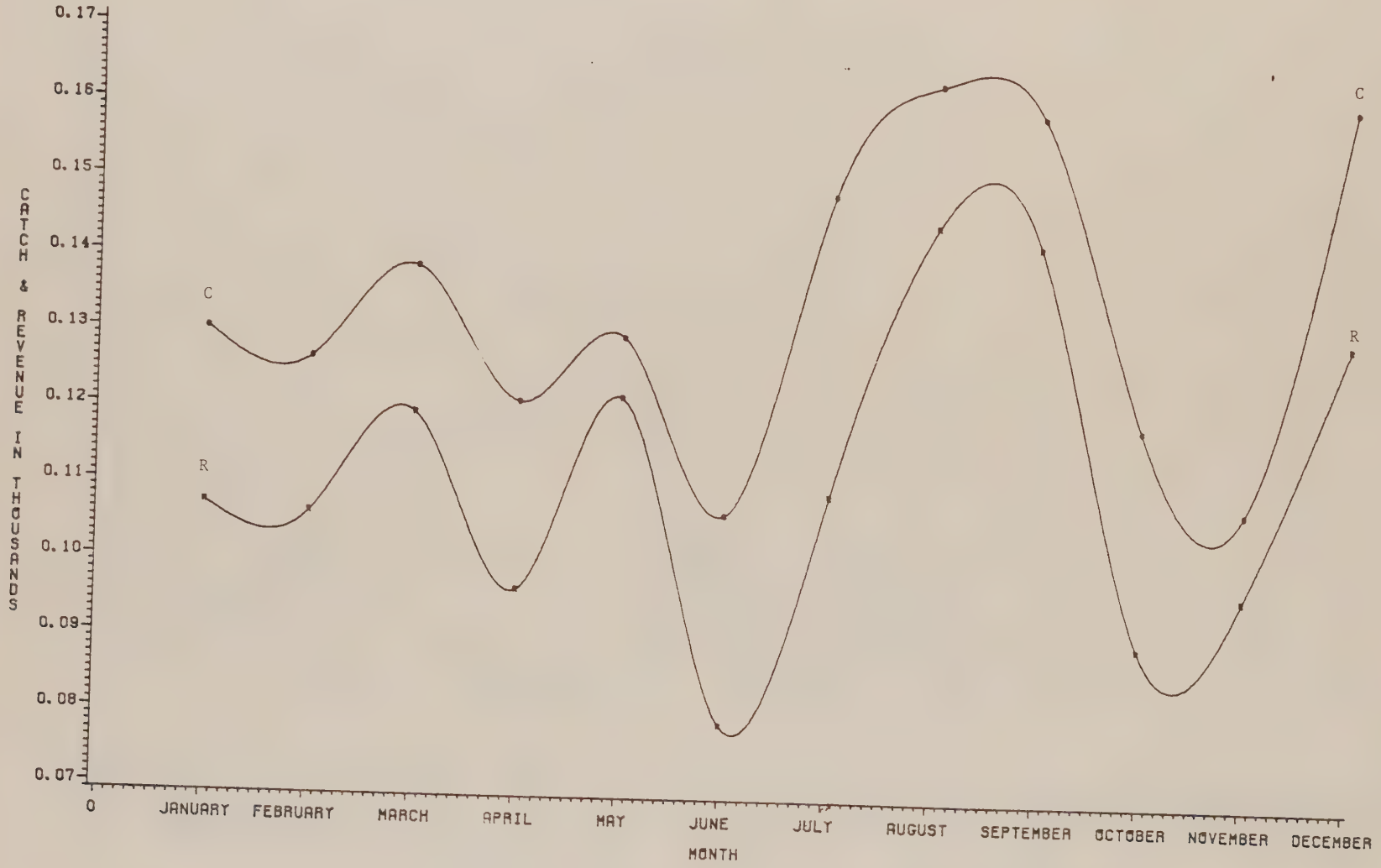

Figure 3-B.--Gindai. Monthly catch and revenues, 1949-78.

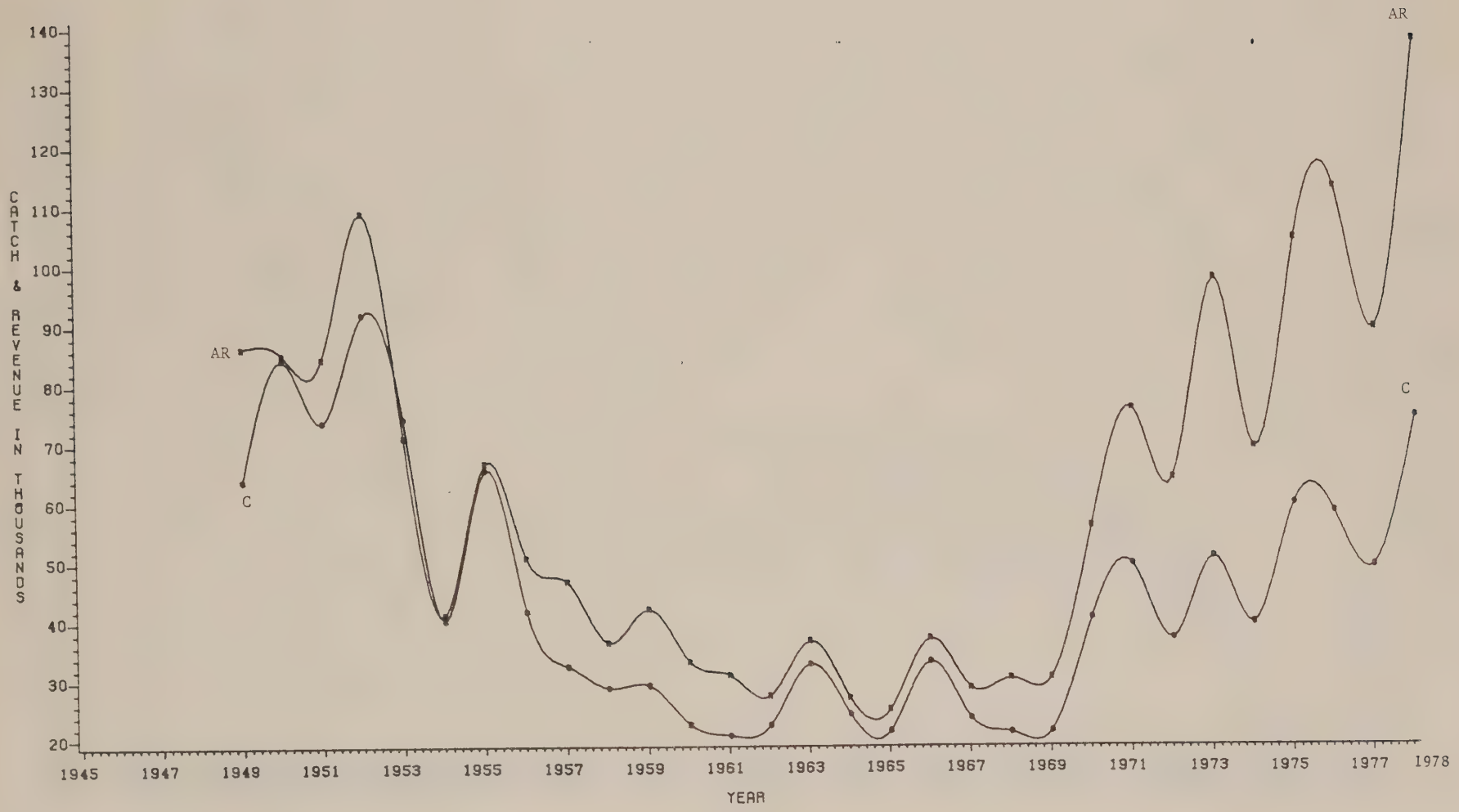

Figure 4-A.--Hapuupuu. Annual catch and revenues, 1949-78.

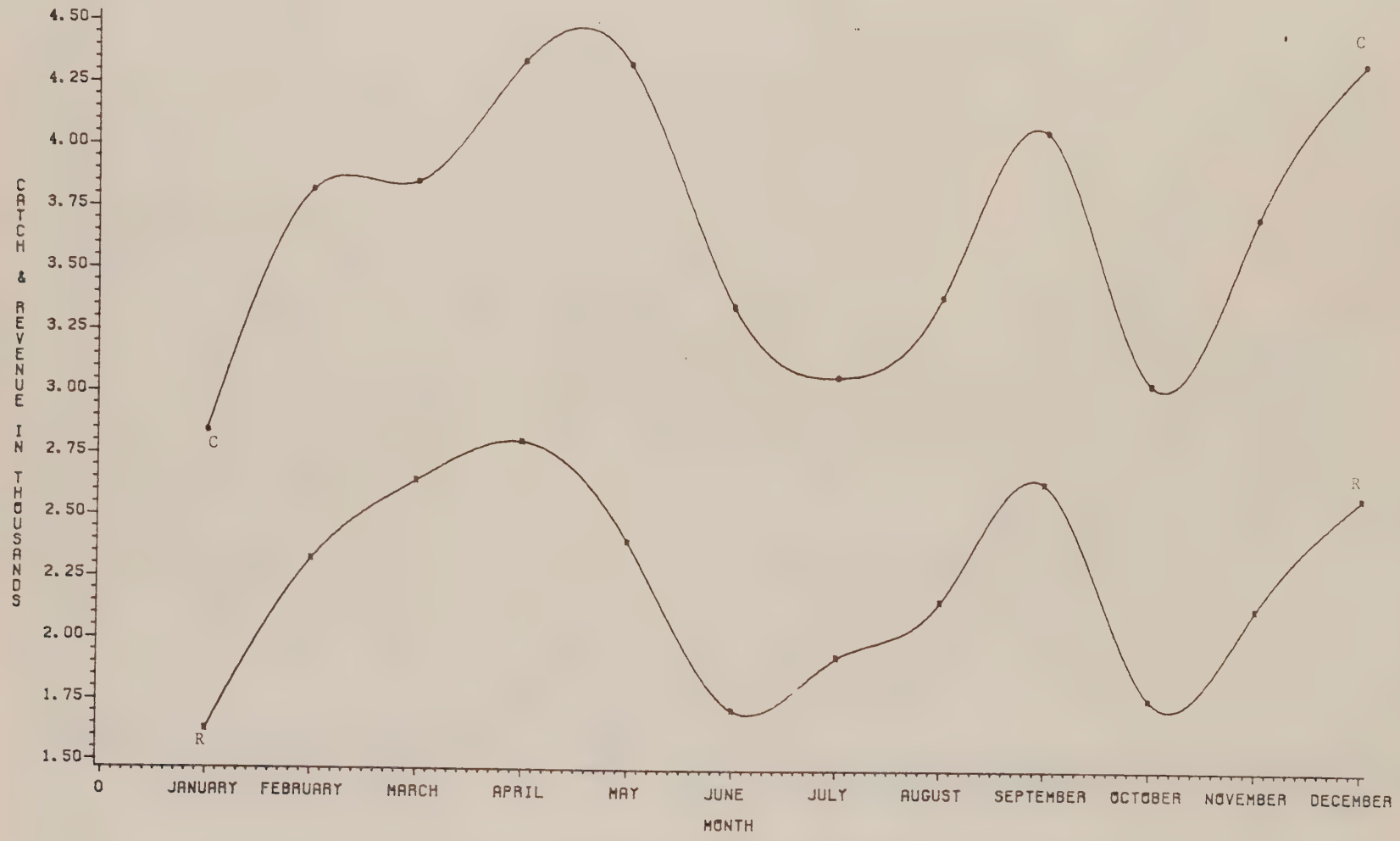

Figure 4-B.--Hapuupuu. Monthly catch and revenues, 1949-78.

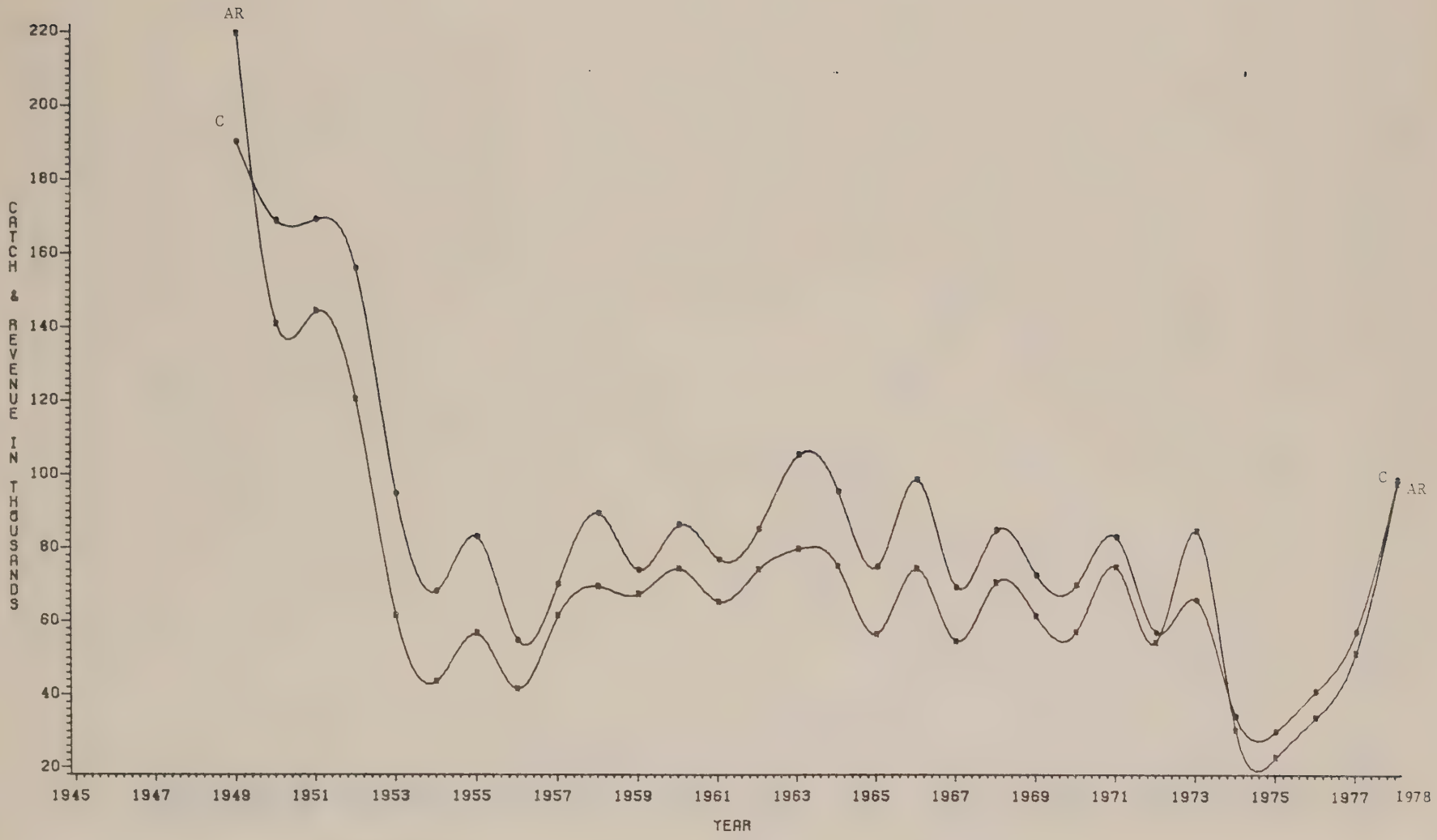

Figure 5-A.--Kahala. Annual catch and revenues, 1949-78.

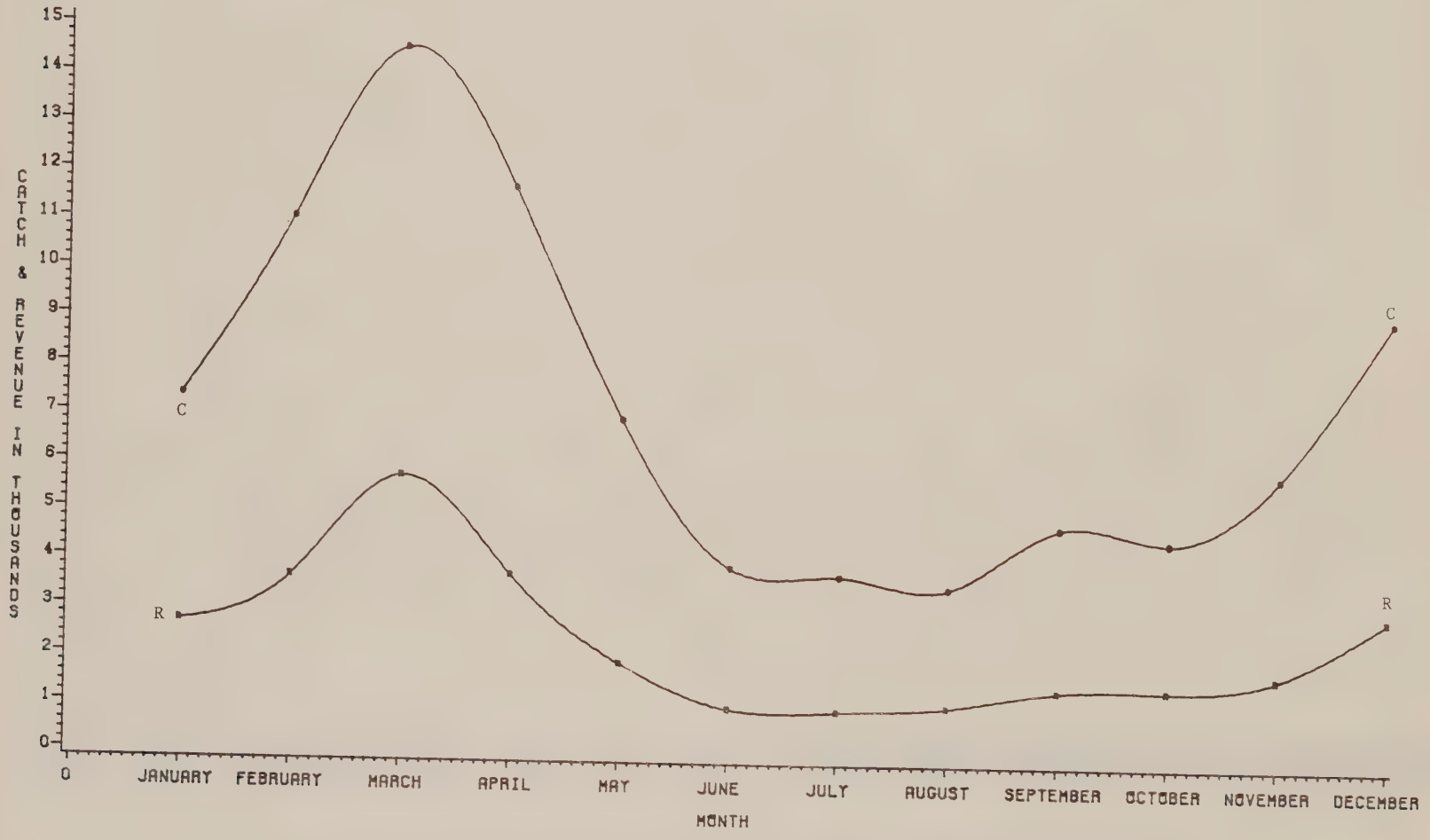

Figure 5-B.--Kahala. Monthly catch and revenues, 1949-78.

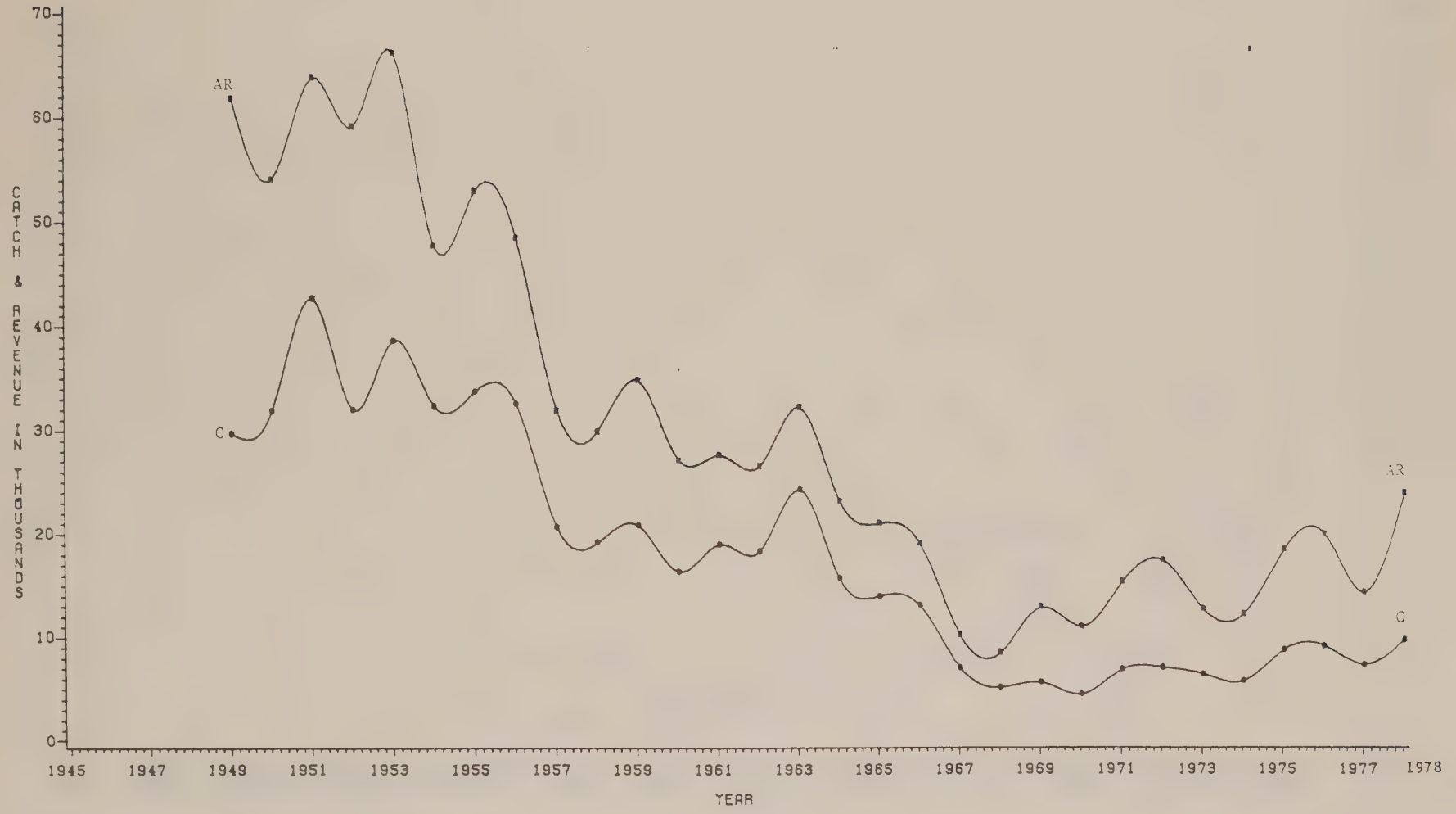

Figure 6-A.--Kalekale. Annual catch and revenues, 1949-78.

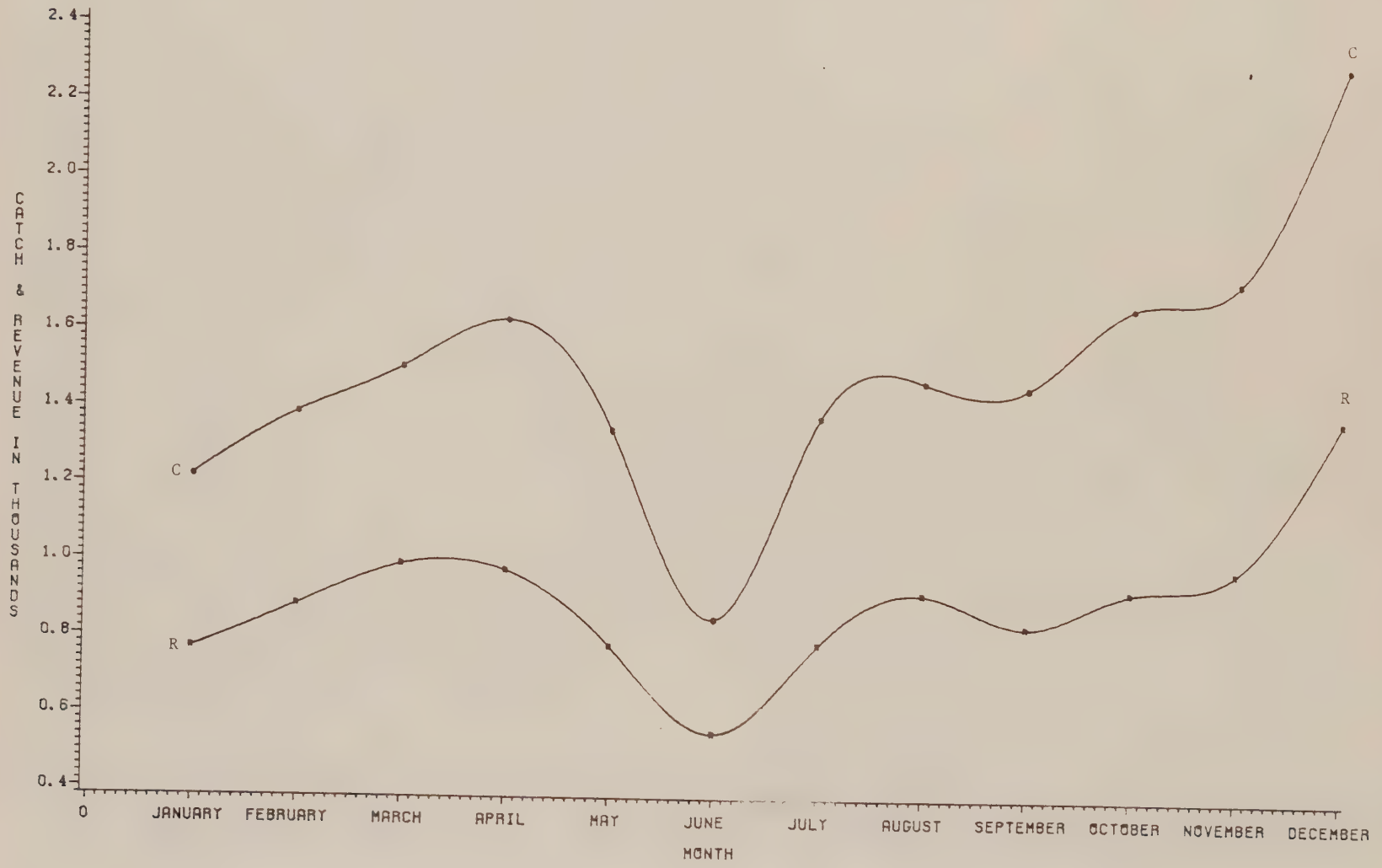

Figure 6-B.--Kalekale. Monthly catch and revenues, 1949-78.

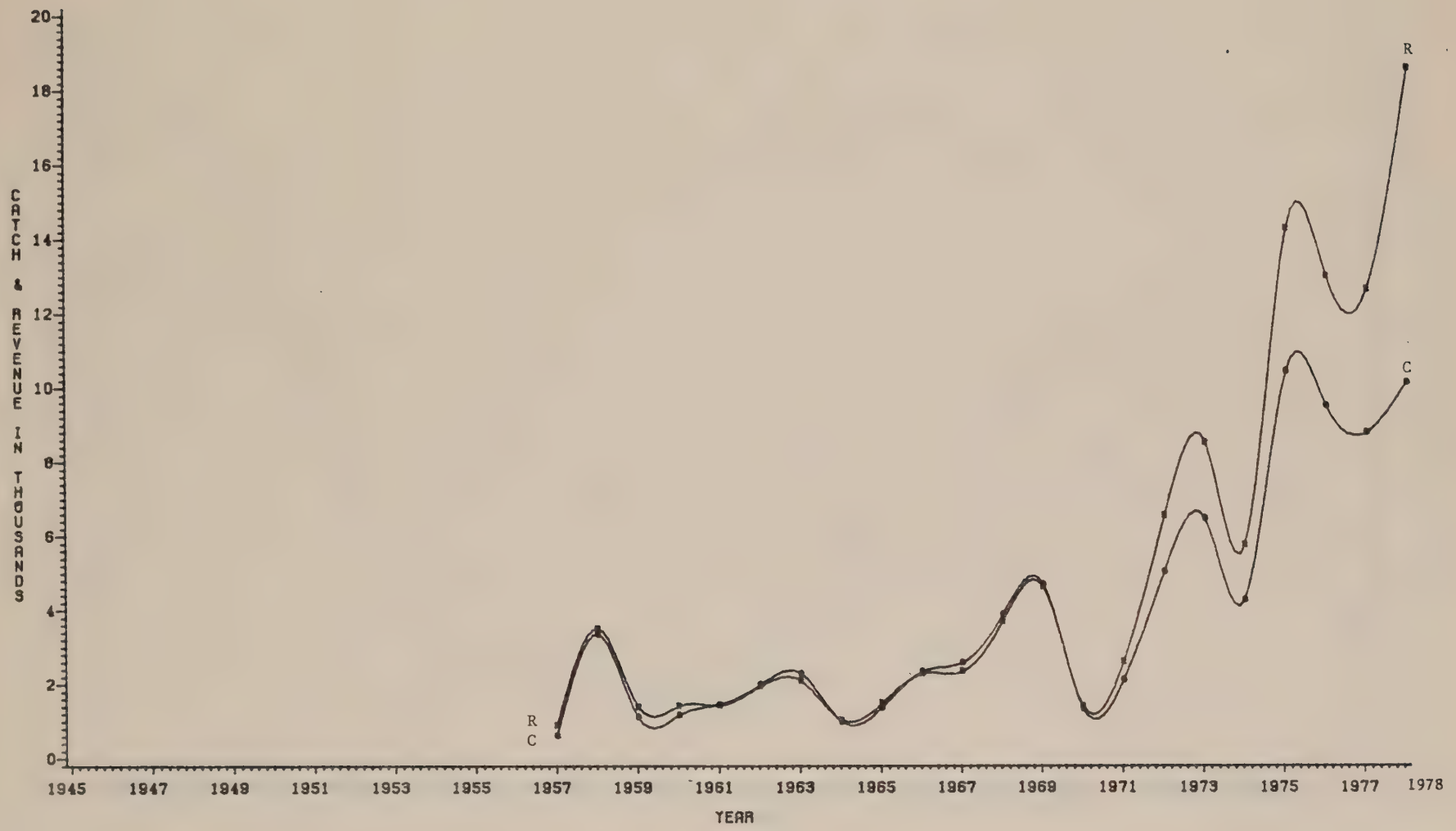

Figure 7-A.--Lehi. Annual catch and revenues, 1949-78.

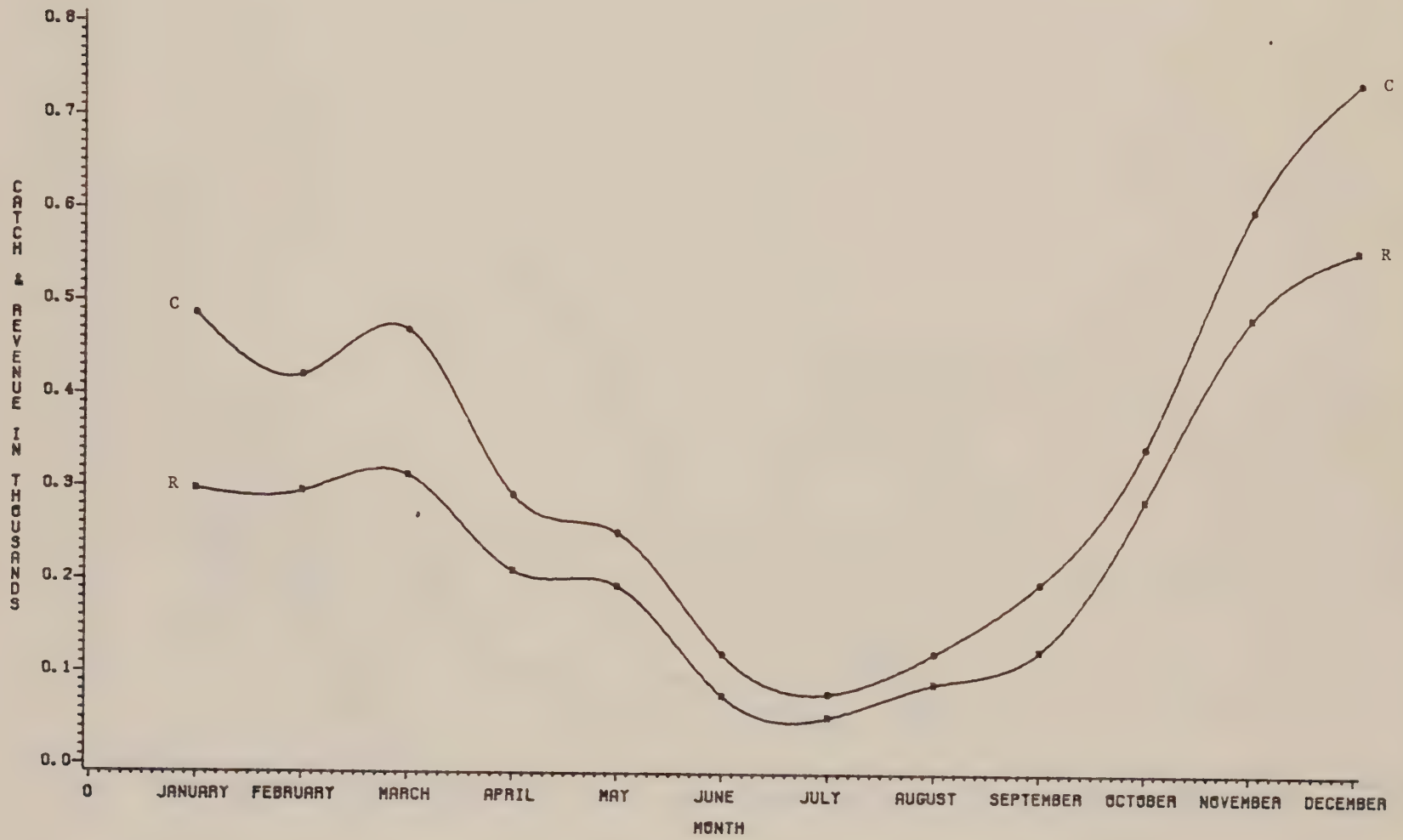

Figure 7-B.--Lehi. Monthly catch and revenues, 1949-78.

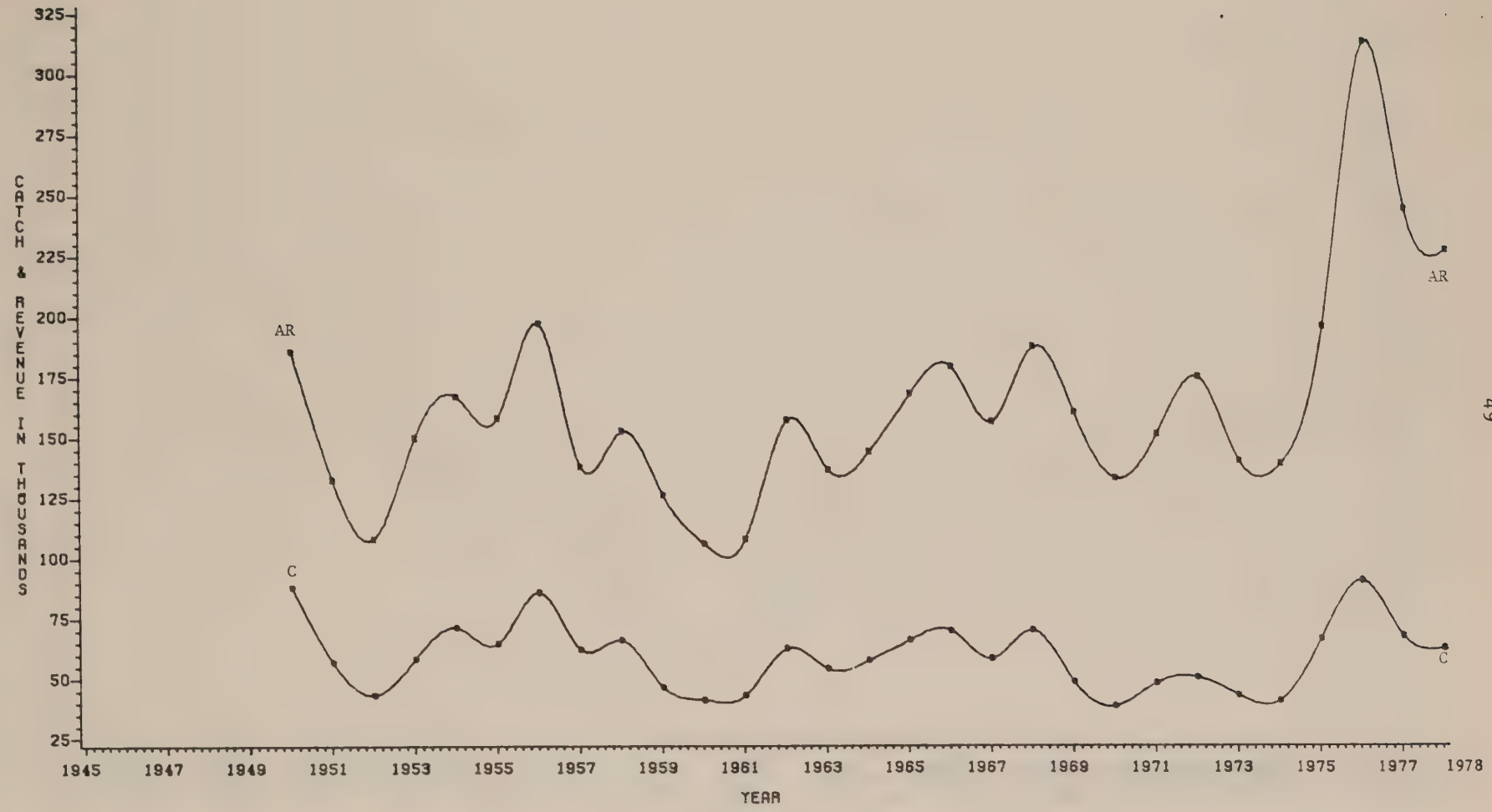

Figure 8-A.--Onaga. Annual catch and revenues, 1949-78.

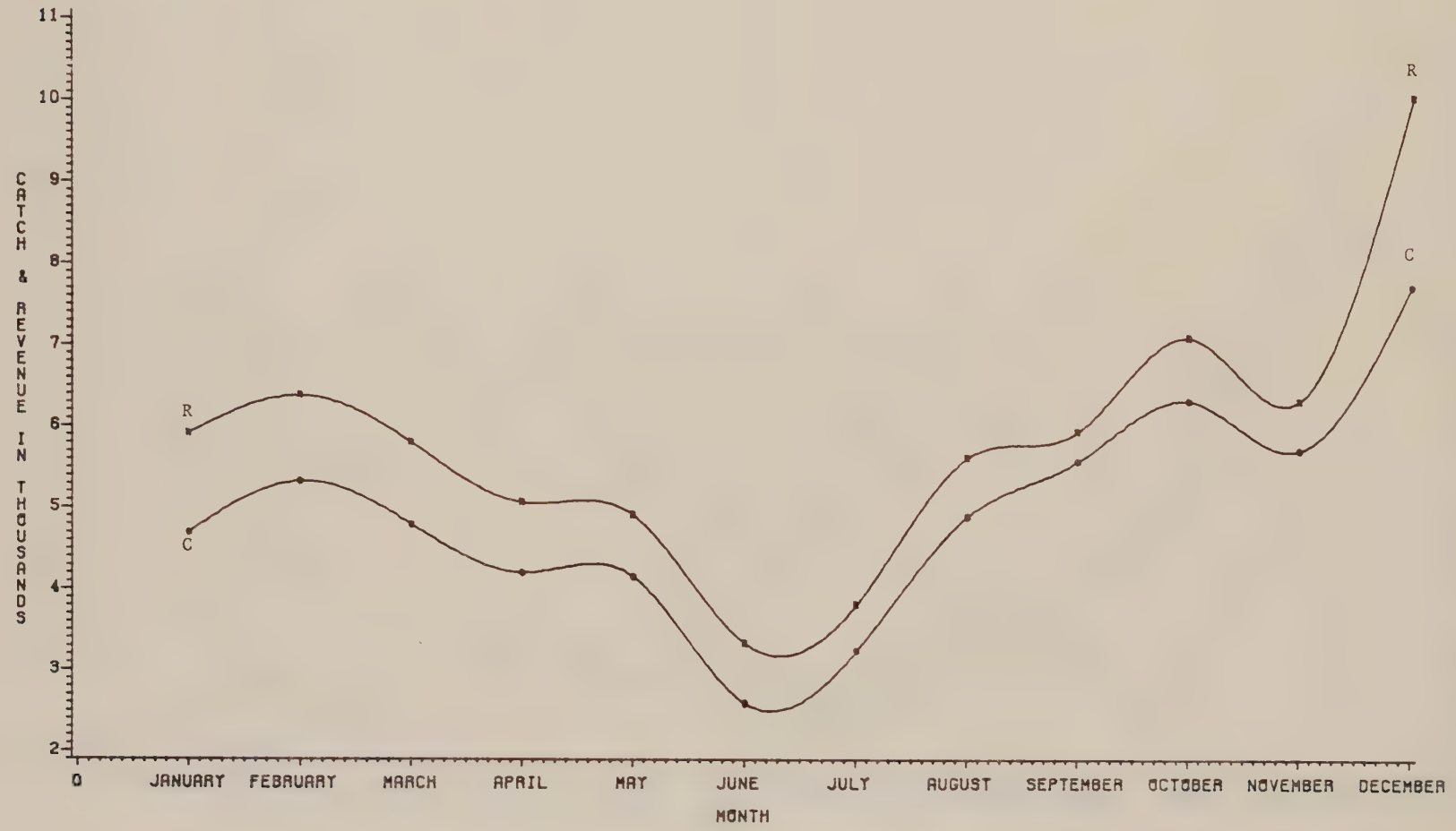

Figure 8-B.--Onaga. Monthly catch and revenues, 1949-78.

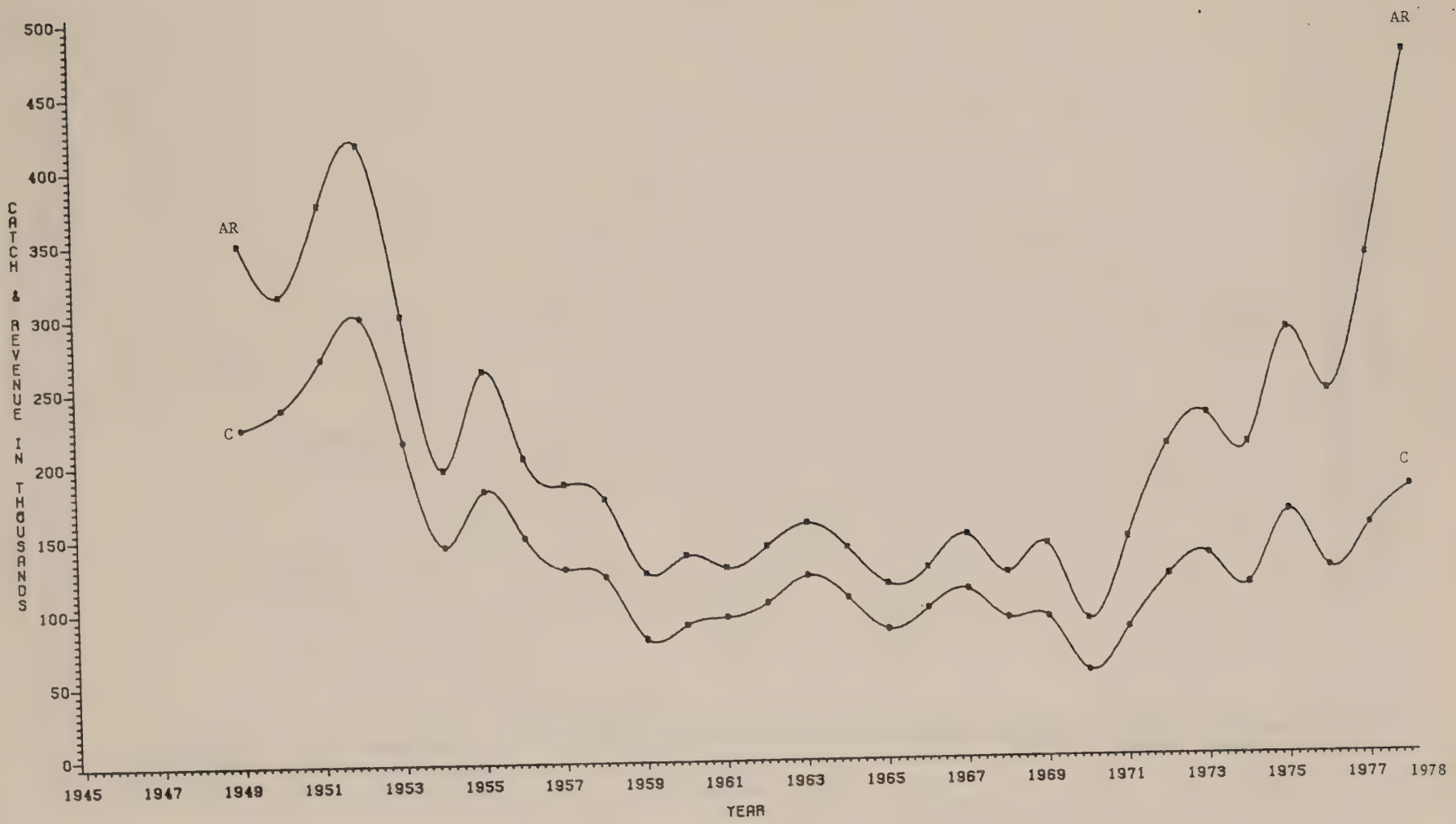

Figure 9-A.--Opakapaka. Annual catch and revenues, 1949-78.

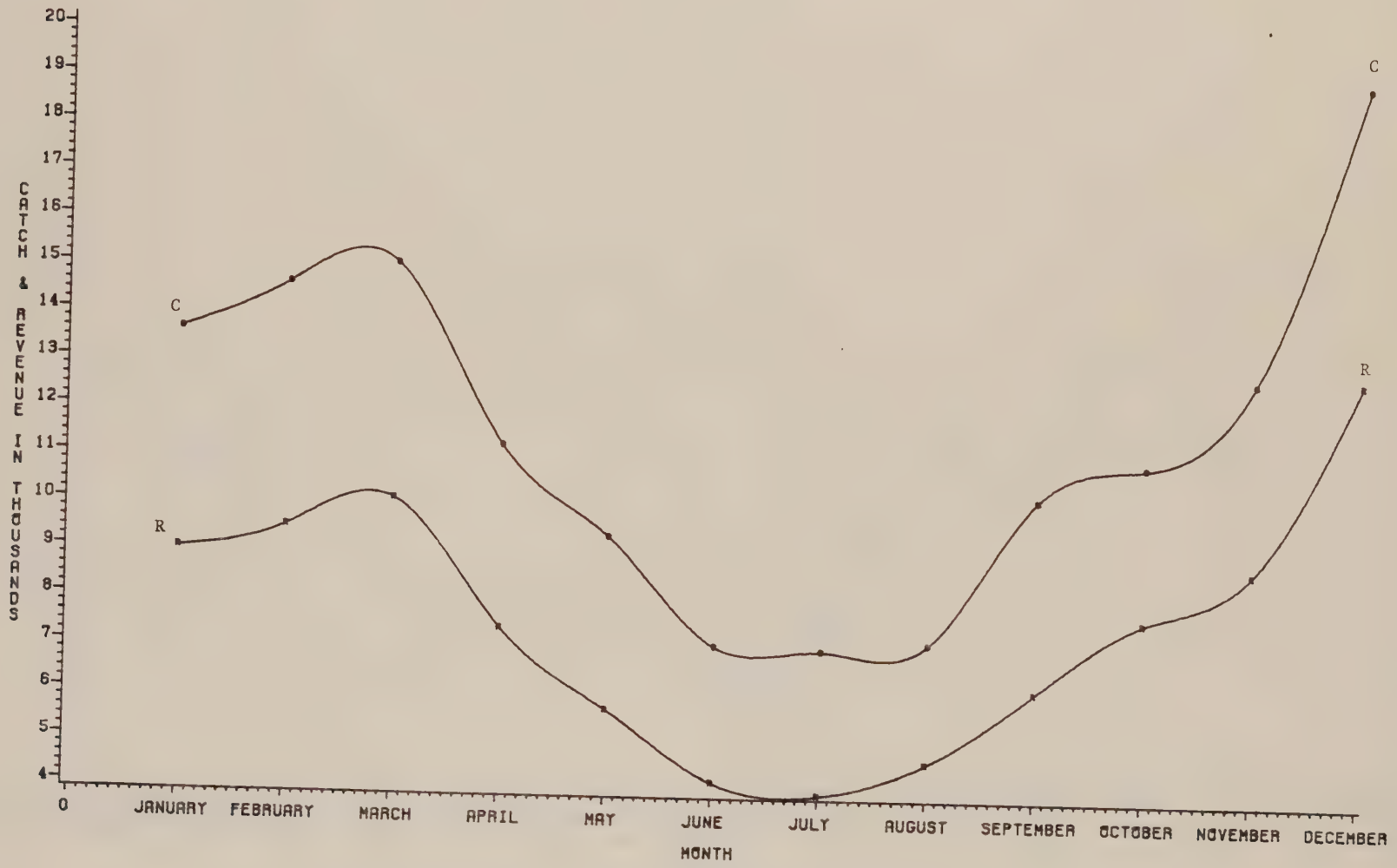

Figure 9-B.--Opakapaka. Monthly catch and reveneus, 1949-78.

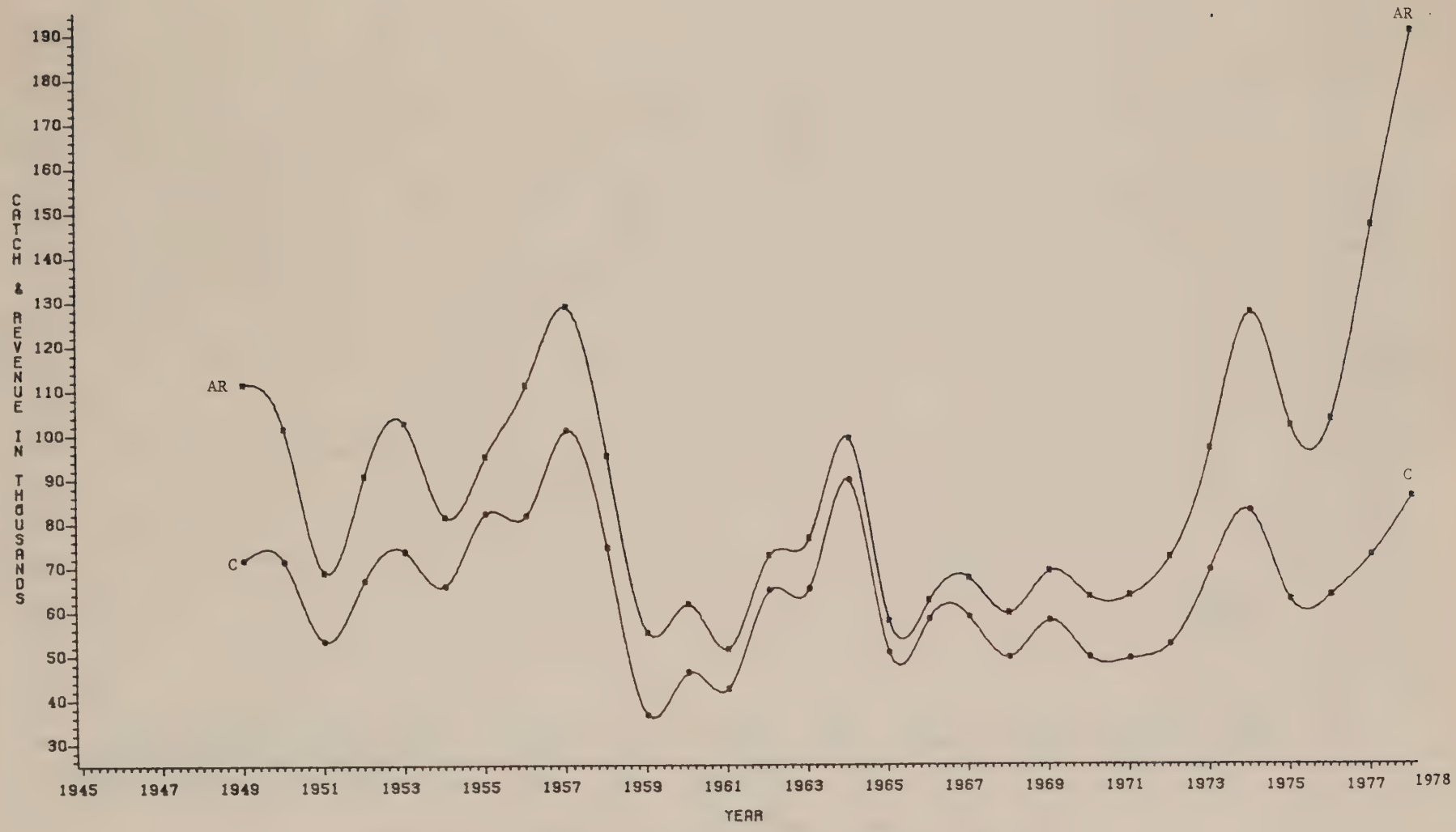

Figure 10-A.--Uku. Annual catch and revenues, 1949-78.

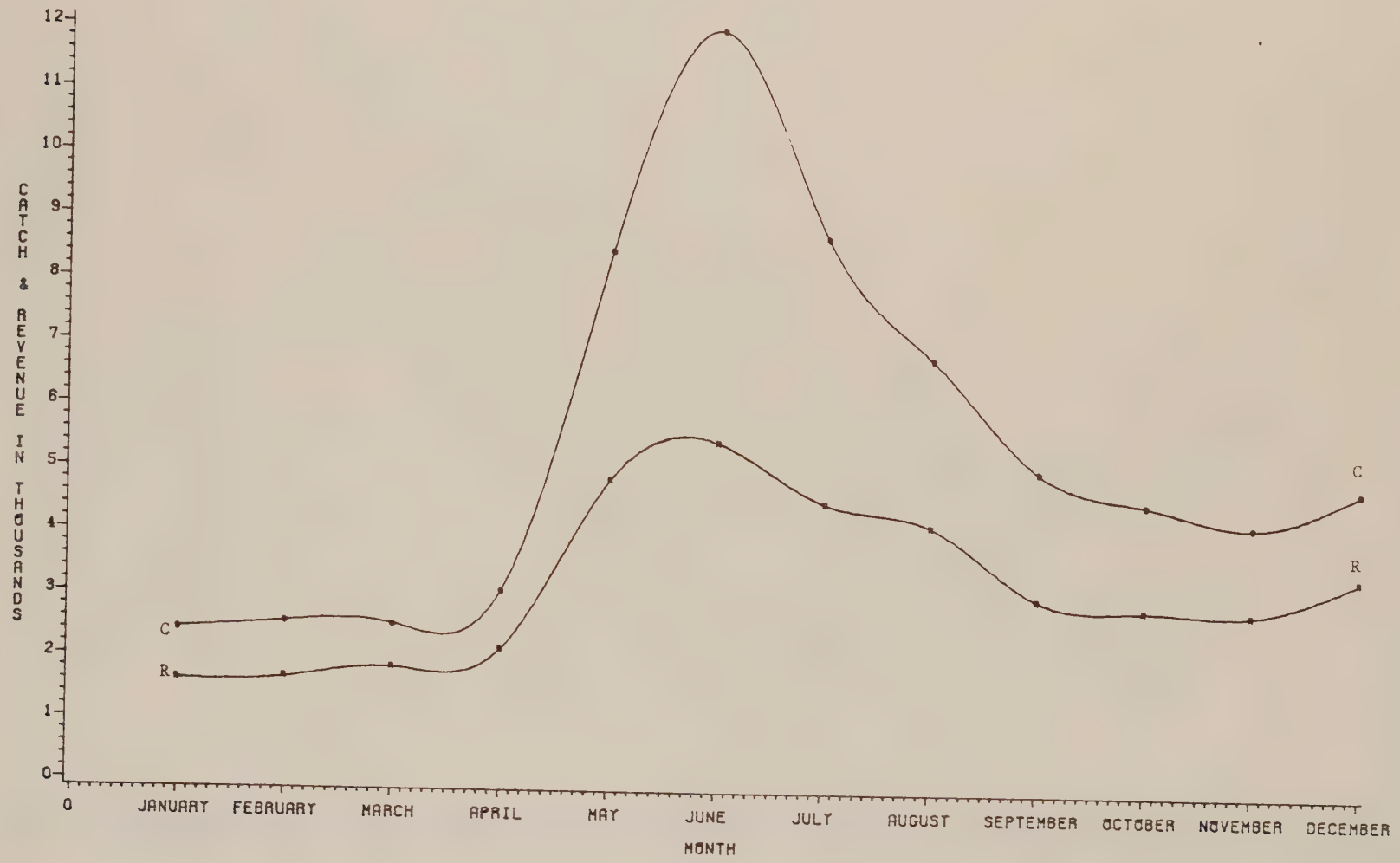

Figure 10-B.--Uku. Monthly catch and revenues, 1949-78.

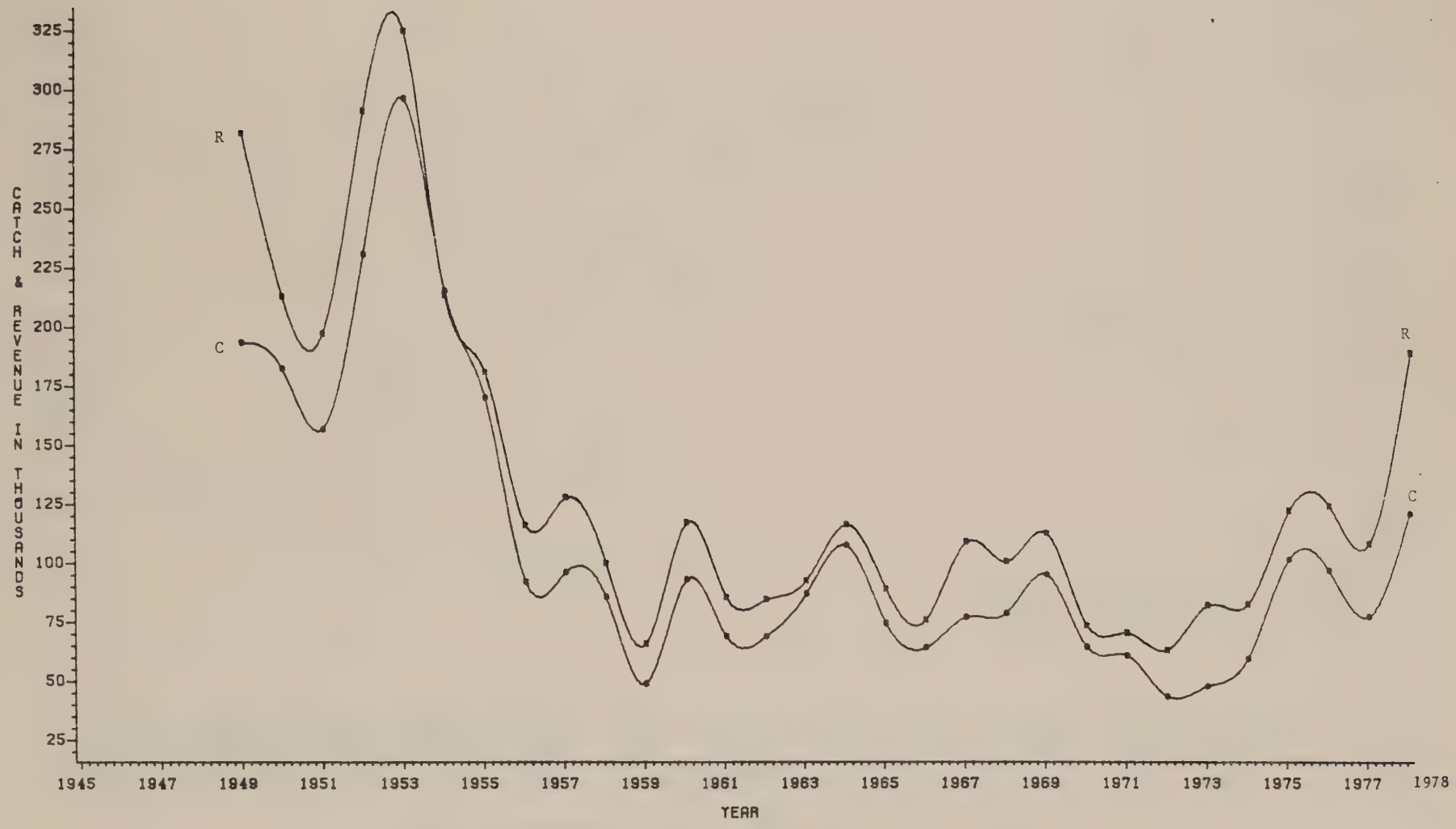

Figure 11-A.--Ulua. Annual catch and revenues, 1949-78.

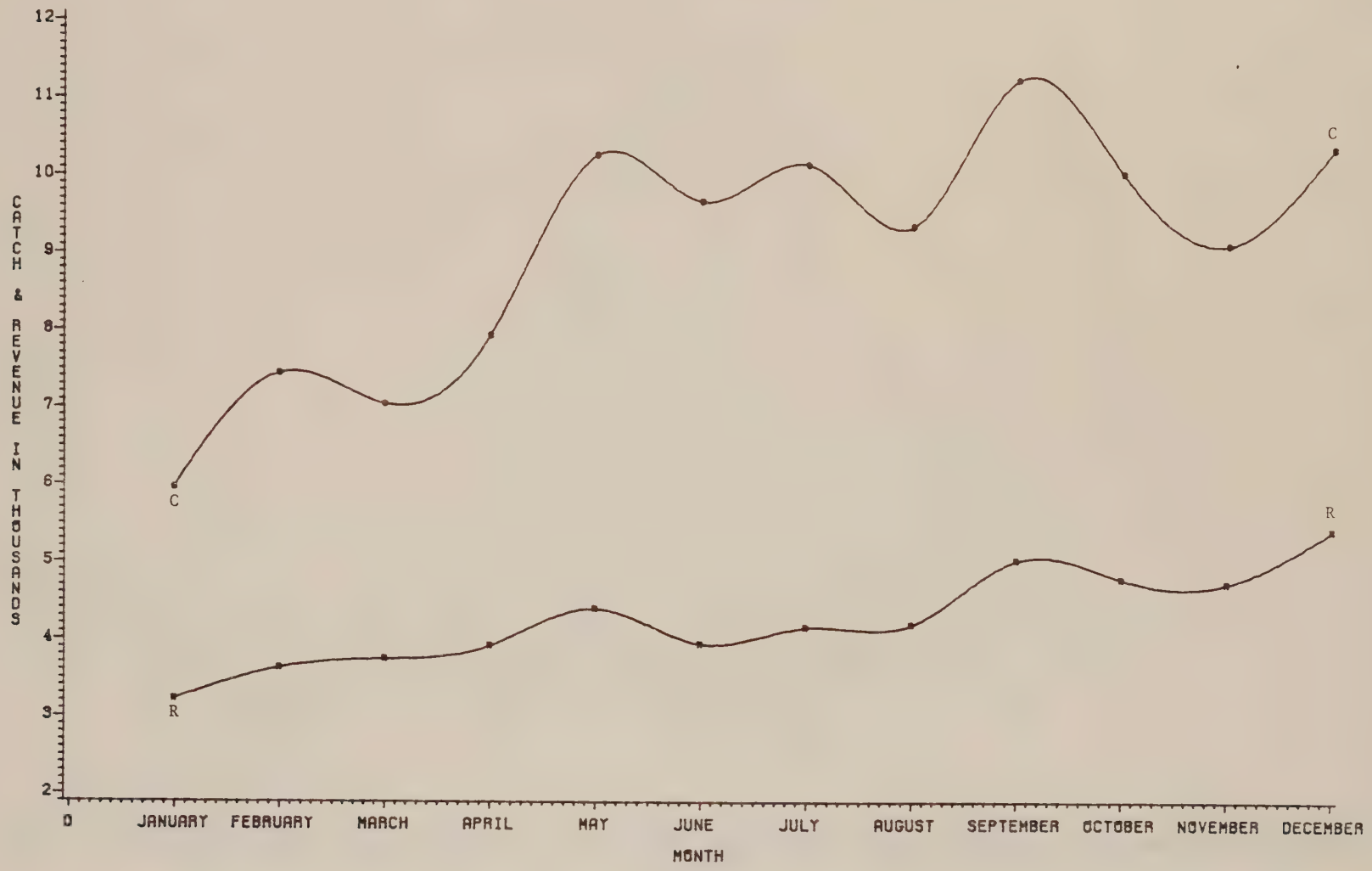

Figure 11-B.--Ulua. Monthly catch and revenues, 1949-78.

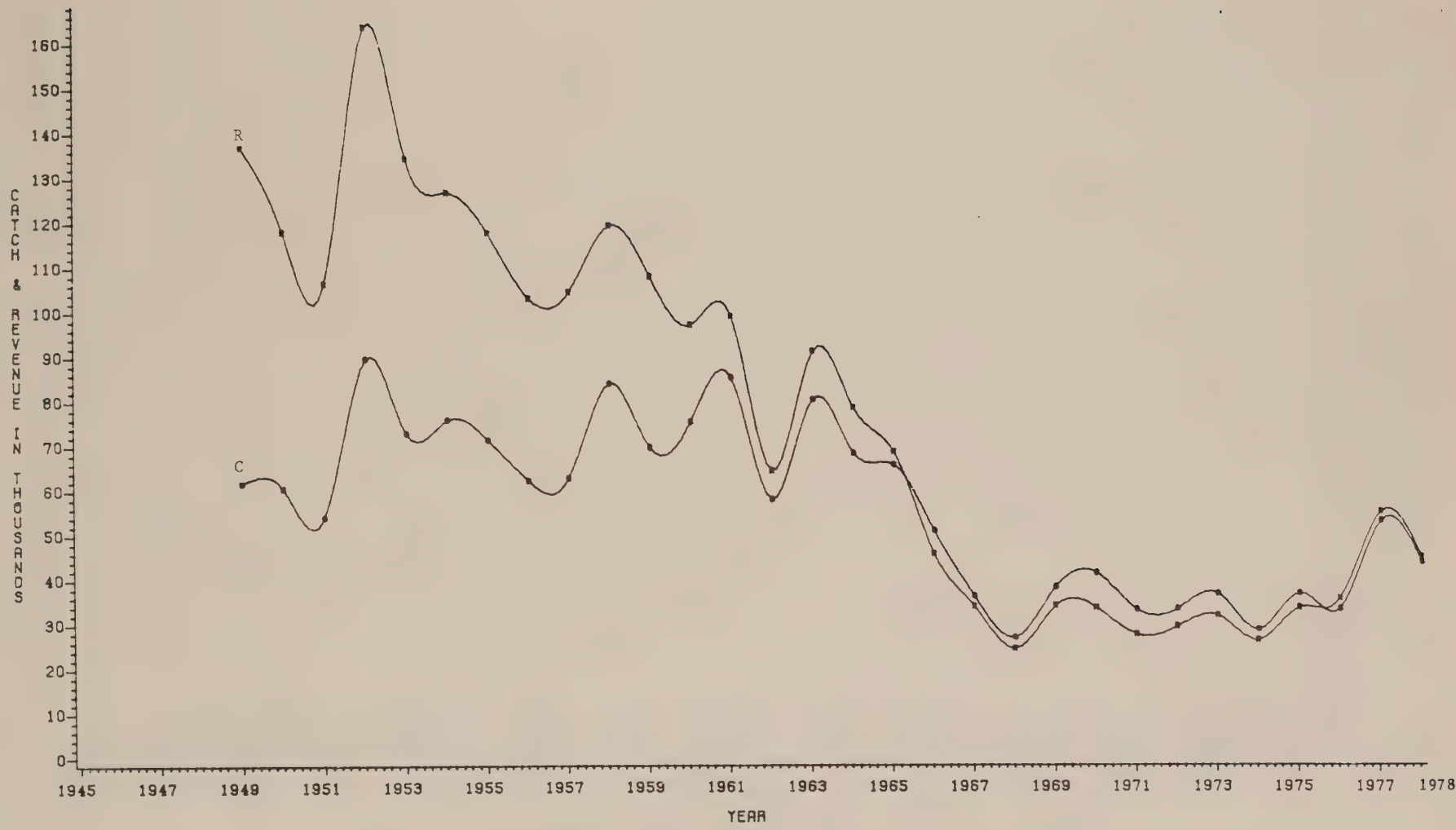

Figure 12-A.--Weke. Annual catch and revenues, 1949-78.

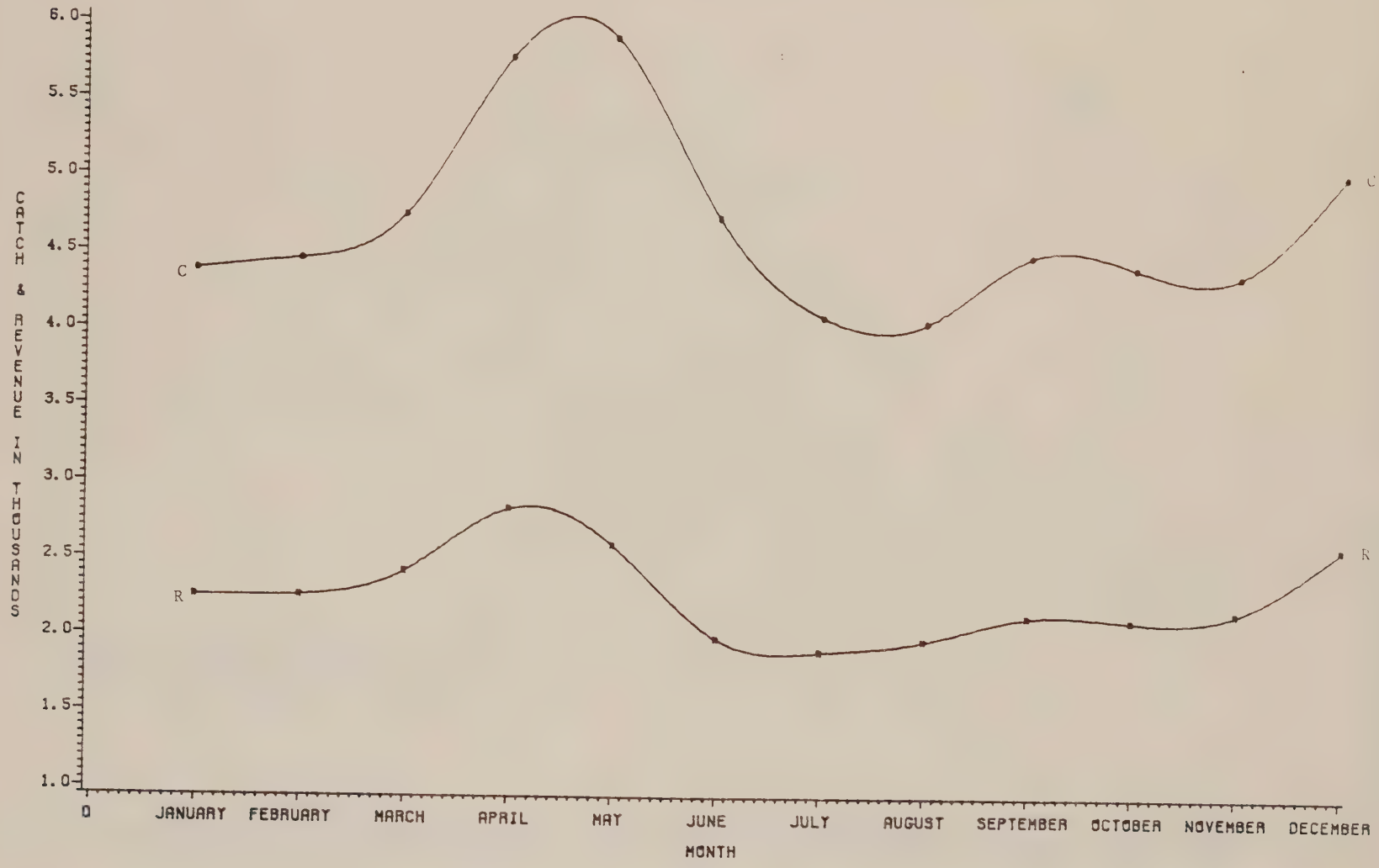

Figure 12-B.--Weke. Monthly catch and revenues, 1949-78.

Figure 13-A.--Taape. Annual catch and revenues, 1949-78.

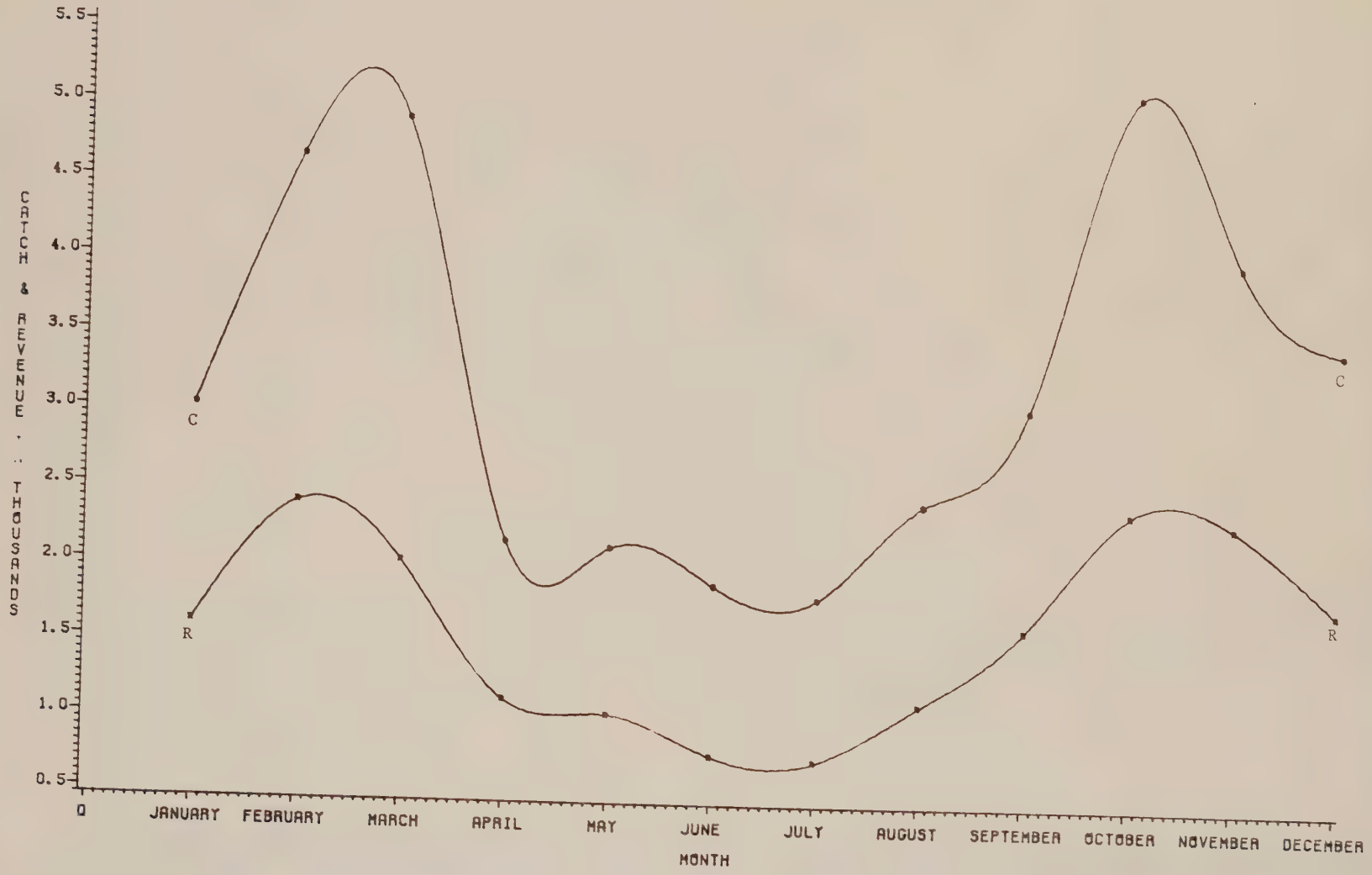

Figure 13-B.--Taape. Monthly catch and revenues, 1949-78.

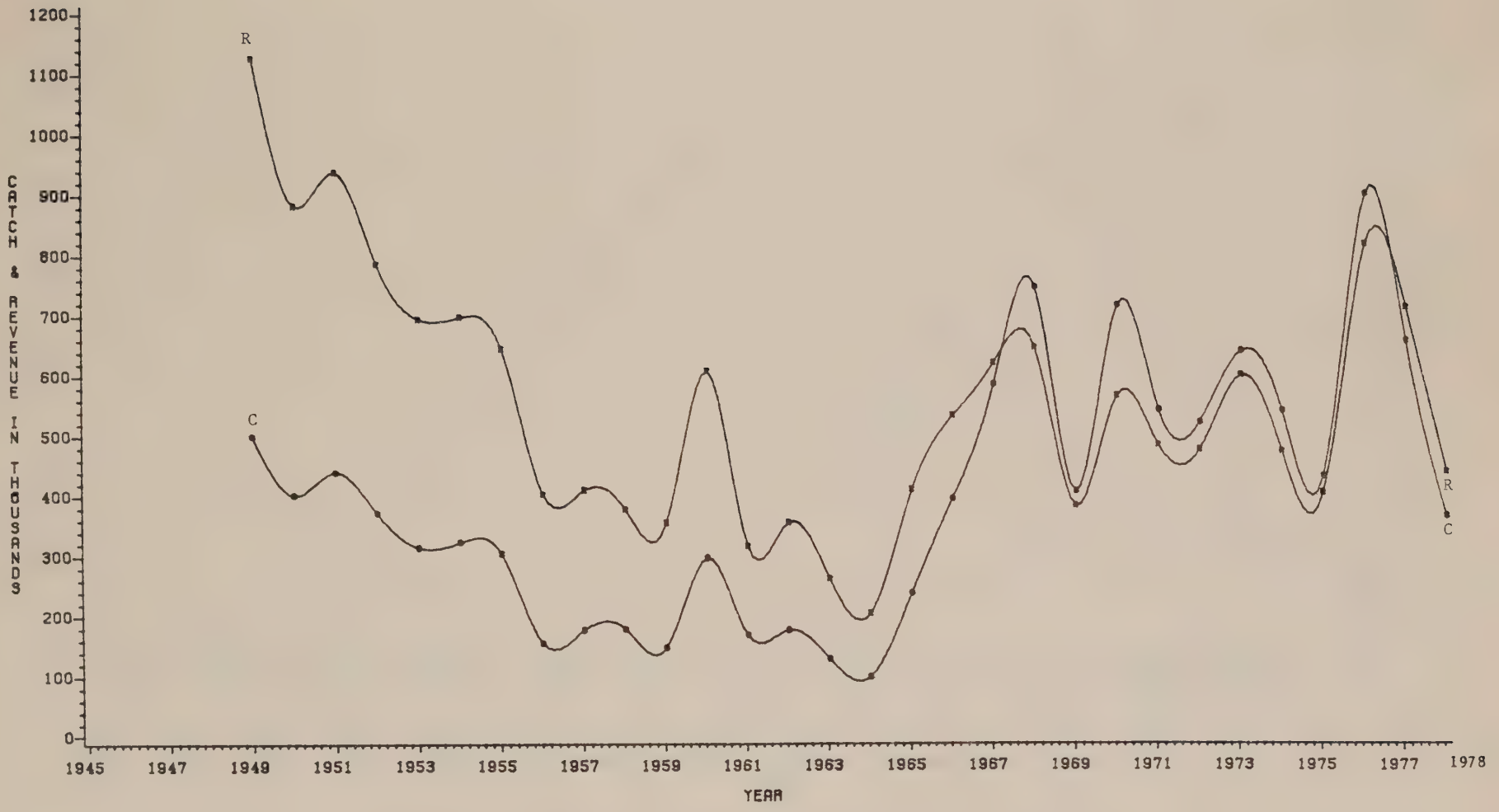

Figure 14-A.--Akule. Annual catch and revenues, 1949-78.

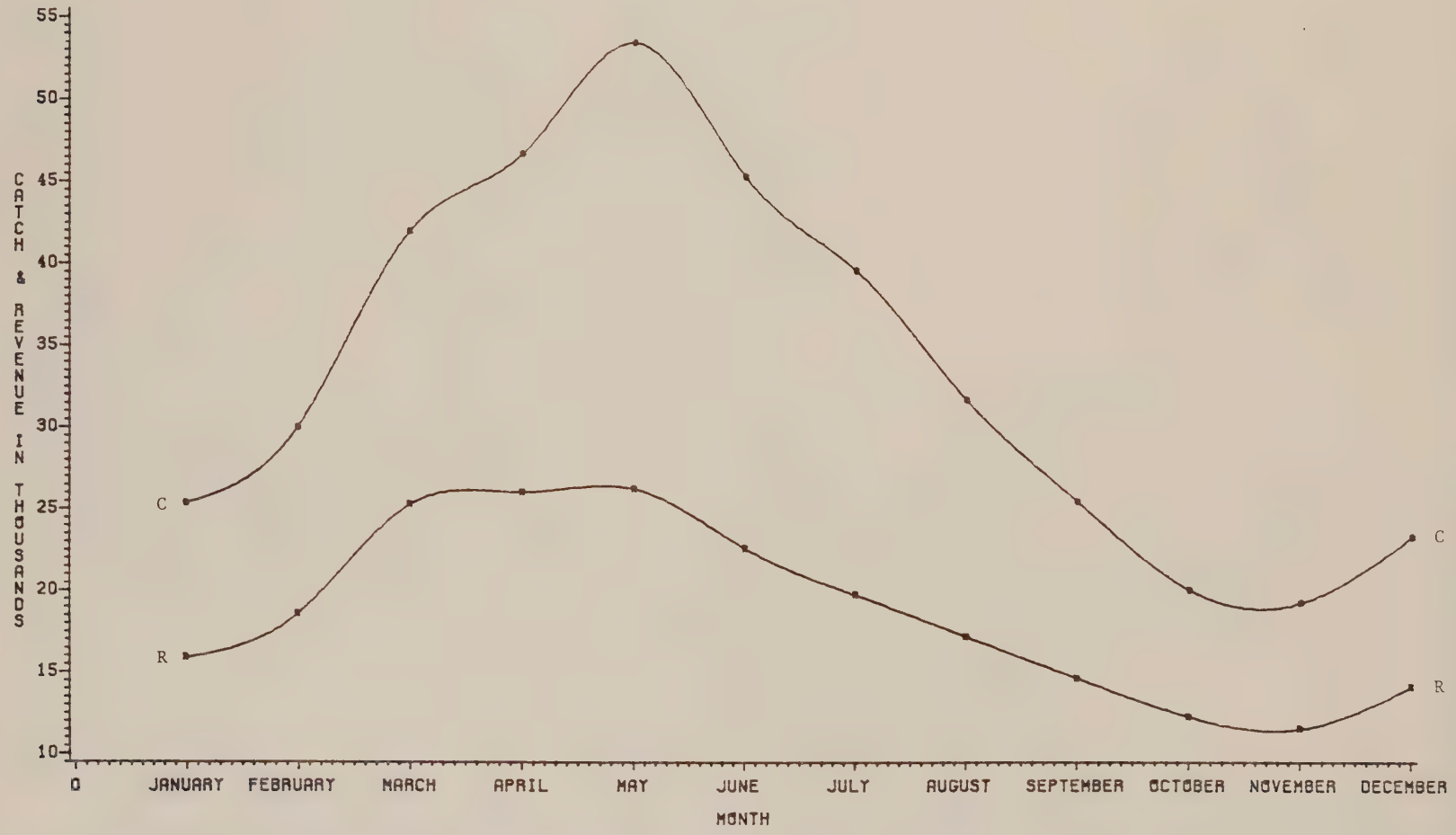

Figure 14-B.--Akule. Monthly catch and revenues, 1949-78.

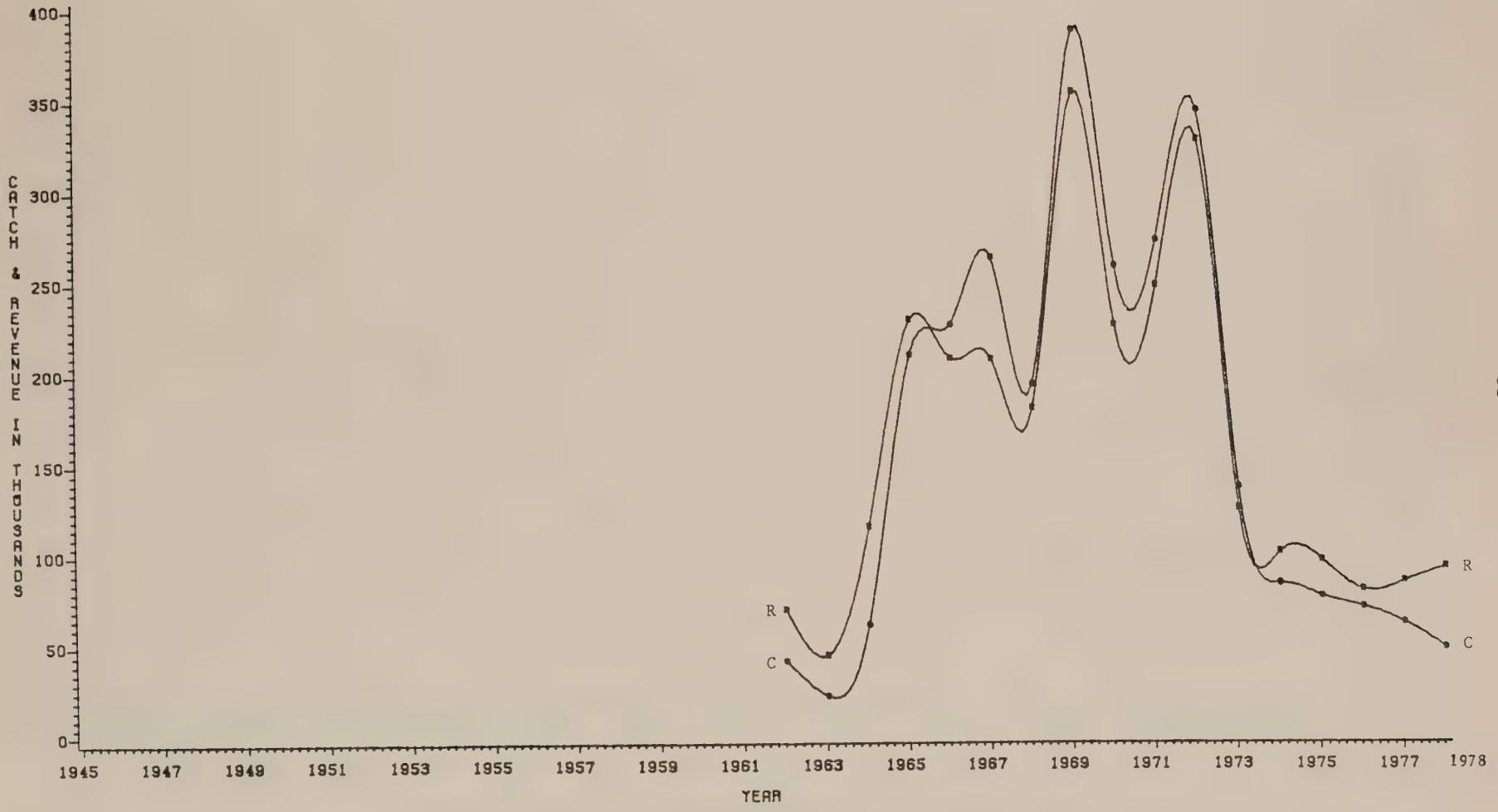

Figure 15-A.--Hahalalu. Annual catch and revenues, 1949-78.

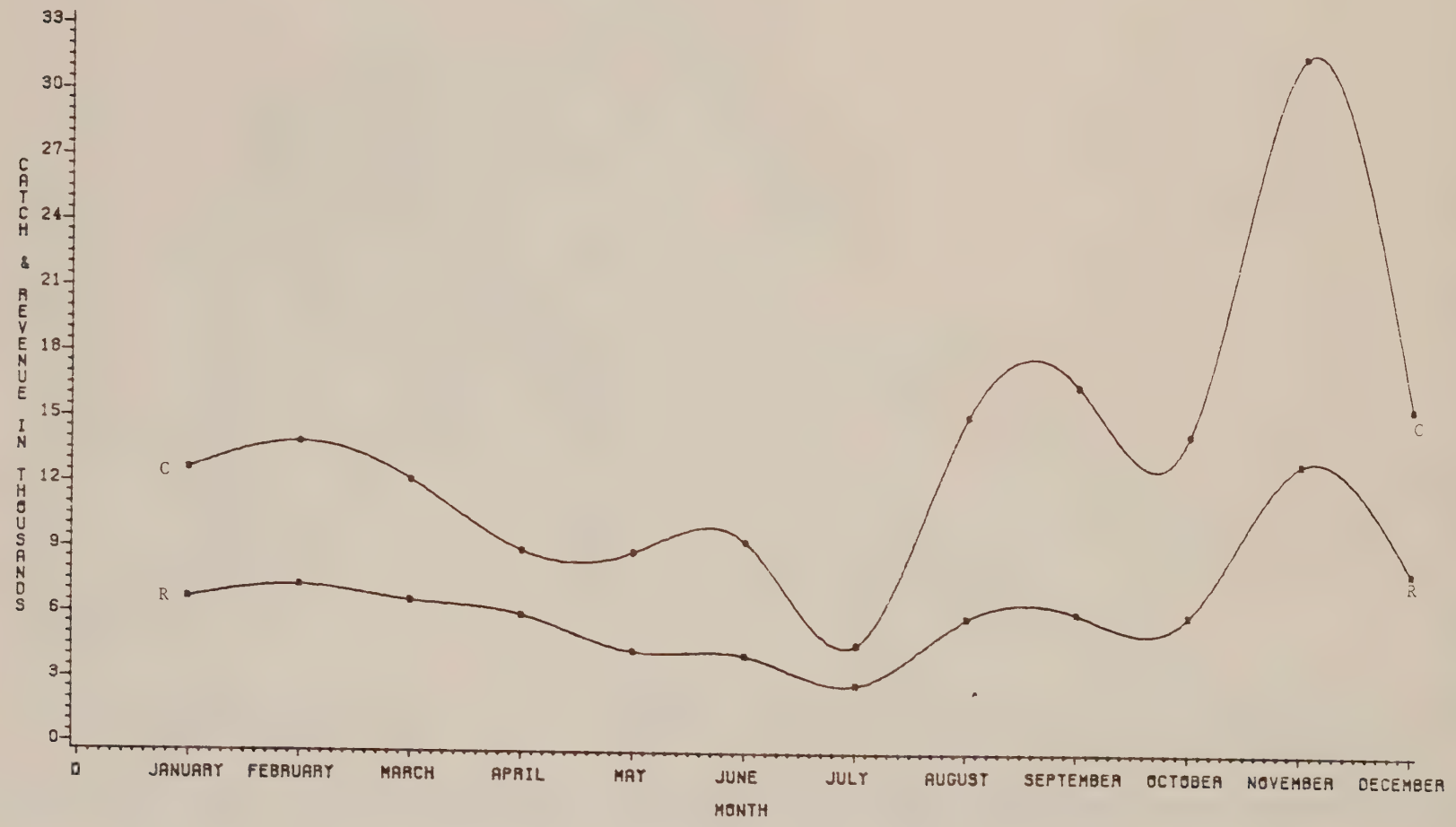

Figure 15-B.--Hahalalu. Monthly catch and revenues, 1949-78.

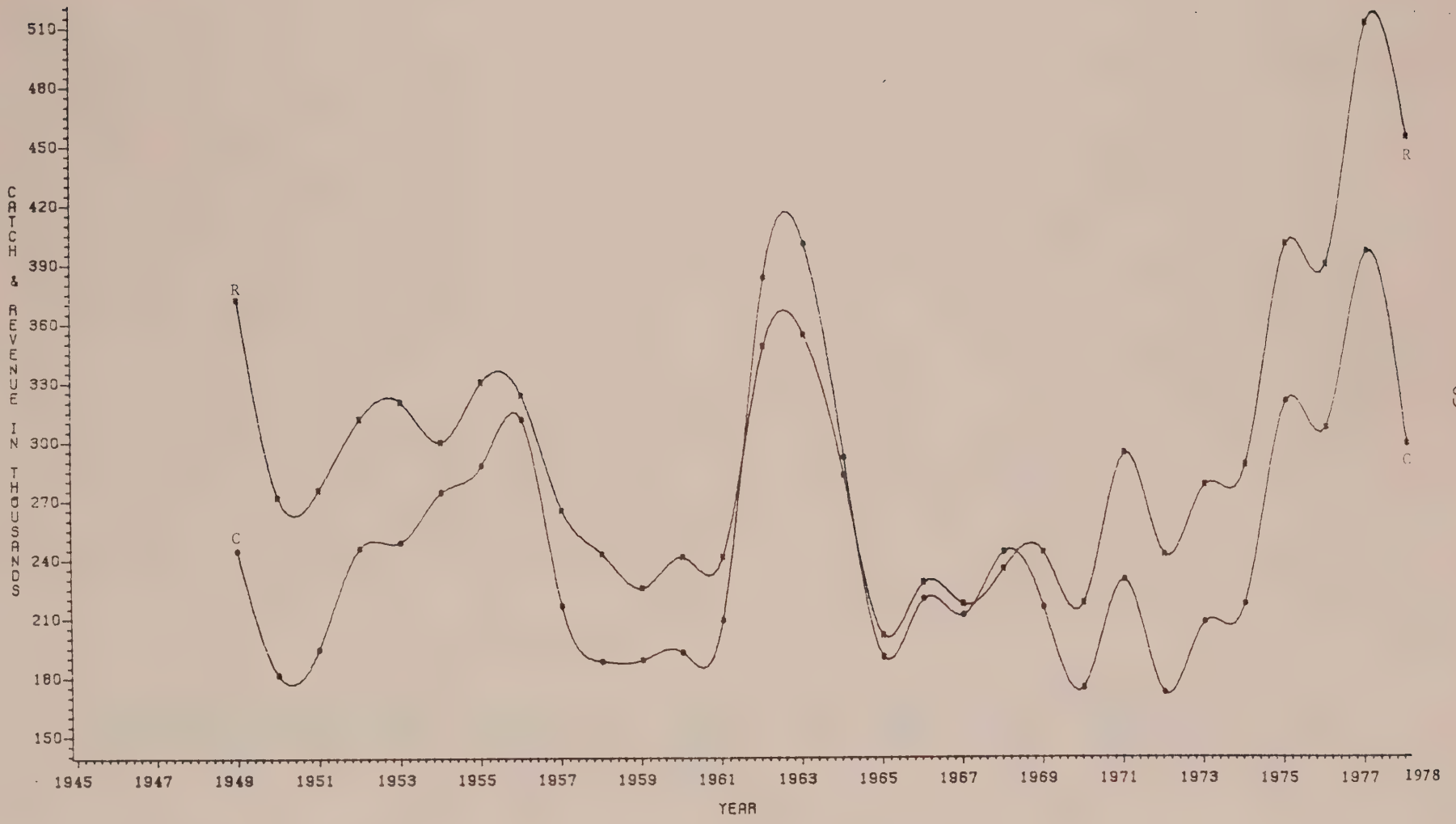

Figure 16-A.--Opelu. Annual catch and revenues, 1949-78.

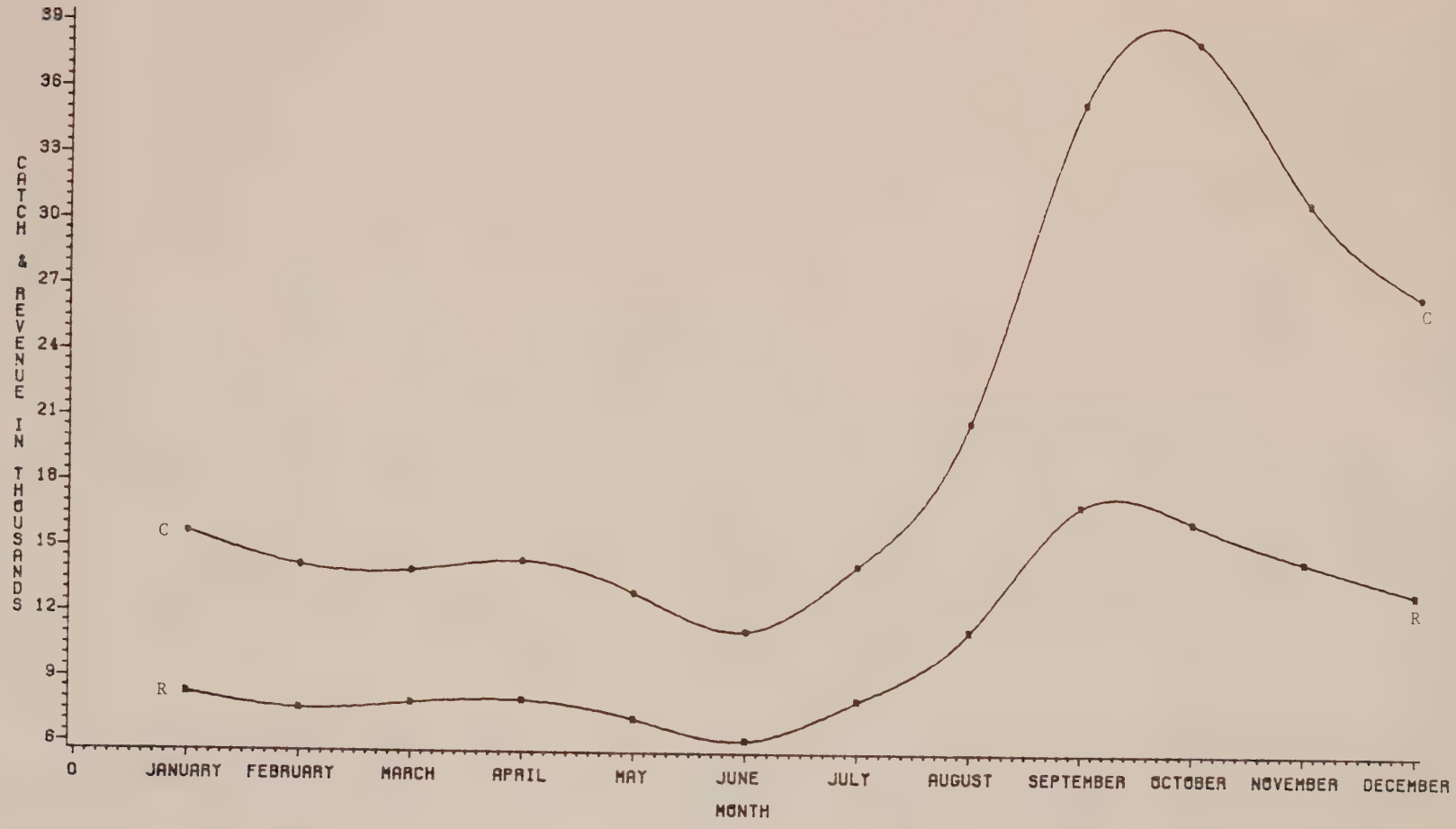

Figure 16-B.--Opelu. Monthly catch and revenues, 1949-78.

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ECONOMIC AND FINANCIAL ANALYSIS OF HAWAII'S LONGLINE AND HANDLINE FISHERIES

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Not for Publication

ADMINISTRATIVE REPORT H-84-17C

II - HISTORICAL OVERVIEW

During the 1940's and through the 1960's, Hawaii's fishing industry experienced either losses or no growth in the volume weight of the catch landed. It was not until the early 1970's that a renewed interest in the State's fisheries began to emerge and not until the second half of the seventies that this interest resulted in actual gains in investment, employment, and productivity. The following sections discuss the various fisheries considered in this study.

LONGLINE FISHERY

The longline fishery, often referred to as the flagline fishery, experienced substantial decline in the number of vessels over the past 30 years. Despite this decline, it appears that the fleet is experiencing renewed growth, given that seven longliners have been added to the fleet since 1969. Additionally, the market remains strong for the longline yellowfin tuna catch, and the development of air-freighted exports of ahi to Japan has increased the demand for, and price of, the longliners' catch.

The longline fishery's main catch are yellowfin and bigeye tuna. The Hawaii Fisheries Development Plan estimates that the potential for yellowfin and bigeye is an additional 11 to 25 million pounds, and that shark and billfish is two to four million pounds. By comparison, in 1976 the estimated catch of these species by longline fishermen was less than one-half million pounds. This suggests that substantial resources remain for further development of the fishery.

REPORT ORGANIZATION

Chapter II of this report briefly discusses the historical perspective of the longline and handline fisheries and the current status of the fisheries' economic performance. Chapters III and IV provides a narrative summary of the financial and economic analysis for the longline and handline survey data, respectively. Chapter V presents a sensitivity analysis and discusses selected management and development policies.

Limited response to the survey questions concerning revenues and the failure to explicitly query the palu ahi and the ika-sibi tuna handline fisheries made it necessary to modify both the cost-earnings and policy/management analysis. The need to make these revisions results from several problems beyond our control including the following:

(1) The data sets for both longline and handline fisheries were found to be of little analytical value because very limited revenue data was obtained. For the longline, only two of the interviews had any revenue data. In the case of the handlines, less than 50% of the observations have any sales data, presenting a serious degrees of freedom problem for testing most fishery economic models. **It should be noted that the degree of inconsistency and non-response for the handline vessels should not be unexpected. It is almost always difficult to collect economic information relating to part-time or non-commercial activities.**

(2) There was no question in the survey instrument that directly relates to distinguishing between the ika-sibi and Palu ahi fishing techniques used by tuna handline fishermen. It had been presumed that the distinction between the two types of tuna fishermen could be determined based on the species of the fish they caught. However, this proved not to be the case.

(3) Additionally, one can only use catch and/or sales data, to the extent it is provided by respondents, to infer which fishermen are primarily involved in the tuna handline fishery and which are primarily involved in the deep sea bottom fishery.

The factors cited above resulted in the need to concentrate on analysis of variable costs per day at sea. The cost-earnings analysis is limited to analysis of the volume weight of fish required to breakeven and to achieve a 25% return on investment. The analysis of fishery management and development policies, presented in Chapter V, focuses on policies related to maintaining sustainable yields, reducing costs, and increasing per unit sales prices.

I - INTRODUCTION

A. Lono Lyman, Inc. was engaged as a subcontractor by Hawaii Opinion to provide financial and economic analysis in conjunction with the cost-earnings study contracted for by the National Marine Fisheries Service (NMFS), OMB number 0648-0117. Hawaii Opinion was the prime contractor for the study responsible for the conduct of the study survey, preparing a computer tape of the survey results, and preparing the final report(s) for the study including incorporation of this narrative material with any material that Hawaii Opinion may add.

The primary responsibility of A. Lono Lyman, Inc. was to establish proto-types based on the cost-earnings data derived from the survey. A secondary area of responsibility was to provide a narrative summary that described the model and its output, to discuss the historical perspective of the longline and handline fisheries and the current status of the fisheries economic performance, and to discuss the potential impacts of a limited number of management and development policies.

REVISED SCOPE OF REPORT

Hawaii Opinion's proposal to conduct the work had anticipated that one general proto-type would be developed for each of four fisheries involved in the study. These fisheries were: the longline fishery, the palu ahi and the ika-sibi tuna handline fisheries, and the deep sea bottomfish fishery.

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PREFACE

This report was prepared under contract (81-ABC-00267) by A. Lono Lyman, Inc. for Hawaii Opinion, Inc. of Honolulu, Hawaii. The purpose of the project was to present an economic analysis of the Hawaii longline and handline fishing fleets based on survey data provided by Hawaii Opinion (Southwest Fisheries Center Administrative Report H-84-7C).

The data utilized in this analysis represent one point in time, the 1981 fishing year. The economic analysis was limited by three significant constraints: Reluctance on the part of commercial fishers to reveal sales revenue information, difficulties in identifying components of the longline and handline fleets, and a lack of historical time-series information on the economic performance of these fleets. The latter limitation is mediated by previous work done on the longline fleet (cf., Ashan, Ball, and Davidson, Costs and earnings of tuna vessels in Hawaii, University of Hawaii Sea Grant Report AR-72-01, 1972) and by a recent paper on Hawaii's Northwestern Hawaiian Islands bottom fish handline fishery (cf., Hau, Economic analysis of deep bottomfishing in the Northwestern Hawaiian Islands, University of Hawaii Sea Grant Report MR-84-01, 1984). Nonetheless, the data and the analysis contained in this report should be used with care.

Despite these limitations, the economic and financial analysis provides the most recent baseline from which to evaluate fisheries development and management decisions, and from which to extend the information required for more precise analysis. As a contract report, the statements, findings, conclusions, and recommendations cointained in this report are those of the contractors and do not necessarily represent the views of the National Marine Fisheries Service.

Samuel G. Pooley
Industry Economist

Southwest Fisheries Center Administrative Report H-84-17C

ECONOMIC AND FINANCIAL ANALYSIS OF HAWAII'S LONGLINE AND HANDLINE FISHERIES

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Longline fishing occurs at depths of 150 to 300 feet depending on the season and the species. Most fishing takes place within 50 miles of the main Hawaiian Islands, although the larger vessels will occasionally take longer trips to distant grounds.

The longline fleet consists of two relatively distinct segments: single fishery, traditional sampan vessels, and multi fishery vessels which use longline gear in particular fishing activities. Although growth of the latter segment has reportedly been substantial in recent years, the Hawaii Opinion survey, used in this report, concentrated on the traditional sampan vessels.

PALU AHI AND IKA-SIBI FISHERIES

The palu ahi and ika-sibi fisheries are the primary types of tuna handline fisheries. The number of fishermen involved in both methods of fishing has increased substantially over the last ten years and further expansion could occur in the future. The tuna handline fishermen use relatively small vessels and typically have two or three crew members.

Until recently, relatively few if any fishermen practiced the ancient Hawaiian palu ahi method of handline fishing. By 1979 an estimated 100 full and part time fishermen used the method. The palu ahi technique involves the use of a stone sinker which takes a hook on a line and mashed chum (palu) to a depth of 100 to 150 feet. The stone and chum are then released causing a feeding frenzy among fish in the area and the possibility of a catch.

Similarly, as recently as 1971 there were only three or four vessels using the ika-sibi method. By 1979, there were an estimated 100 full time ika-sibi vessels with an estimated 80% based on the island of Hawaii. Very similar to palu ahi, ika-sibi fishermen use a line lowered to depths of about 100 feet. Ika-sibi, however, is done at night and the bait is either imported frozen squid or fresh squid caught by using a lighted jig or a gaff. The squid is attached to the hook and dropped to the desired depth.

The primary catch for the tuna handline fisheries is also yellowfin and bigeye tuna. In 1973, the ika-sibi fishery produced landings of 196,00 pounds and by 1975 the catch had increased to 341,000 pounds. By 1979, the combined palu ahi and ika-sibi catch exceeded one million pounds. The Hawaii Fisheries Development Plan estimates the potential for tuna handline fisheries at three to five million pounds of additional landings.

DEEP SEA BOTTOMFISH FISHERY

There is not much solid data regarding the number of vessels distinctly engaged in bottomfishing. As many as 1,000 vessels may be identified as handline vessels but many of them are primarily ika-sibi or palu ahi vessels. Like the tuna handline fishery, they are relatively small sized vessels and differ significantly from the larger bottomfish vessels studied by Hau (1983).

Despite the lack of historical data, it is generally regarded that the deep sea bottomfish fishery has grown in the last decade. One factor in the growth is the increased price paid for the bottomfish species. Another factor in the growth is the increased cost of fuel for trolling which has led to fishermen turning from trolling to bottomfishing.

The Hawaii Fisheries Development Plan reports that the waters surrounding the larger islands in the Hawaiian chain have been fished to a point that either approaches or exceeds the sustainable yield for bottomfish. The Northwestern Hawaiian Islands may allow for an expansion of this fishery, but this involves larger-sized vessels than those used in the main island fishery.

The fishing technique used by the deep sea bottom fish fishermen is very similar to that used by the tuna handline fishermen. Deep sea lines are used with hooks and chum bait. The fishing depths, however, are much greater, ranging from 180 to 900 feet. The primary catch of the deep sea fisheries is opakapaka, onaga, and uku.

III - LONGLINE FLEET ANALYSIS

OVERVIEW

The longline fleet survey conducted by Hawaii Opinion interviewed the captains and owners of Oahu based longliners. The sample for the longline survey was provided by NMFS staff. A total of thirty eight vessel names and owners, statewide, represented the universe for the survey. This included both "flagline", part-time, and small scale vessels using modified longline gear. Data collection was conducted from June 30 to July 30, 1982. A total of thirteen interviews were completed on Oahu. Additional attempts were made to recontact respondents between December 7 and 15, 1982, in those cases where editing revealed incomplete or missing information. Of the remaining twenty five vessels for which surveys were not completed, Hawaii Opinion could not contact twelve during the survey period, and the remaining thirteen were not based on Oahu during the survey period.

The longline survey had a a poor response rate to questions concerning asset value, financing, revenues, and expenses. Thus our analysis is limited by the reluctance on the part of respondents to provide information. In addition, given that interviews were completed with less than half of the the thirty eight vessels in the longline sample, sampling bias may be reflected in the data that was provided. Our perception is that the vessels sampled comprise the traditional sampan style of longline fishing, and not the newer multi-purpose vessels.

FLEET DESCRIPTION

Based on the surveys completed, Table III-A summarizes selected attributes of the longline fleet. As indicated, the longline fleet vessels have a mean length of 61 feet and mean net tonnage of 25.5 tons. The mean age of the vessels in mid-1982 was fifteen years, indicating that the typical boat was built in the mid-1950s. Of the thirteen interviews completed, respondents indicated that one vessel was built prior to 1940, and another five were built during the period 1940 to 1949.

TABLE III-A

Selected Attributes of the Longline Fleet

		Respondents Providing Data
Length of boat	61.2 feet	13
Net Tonnage	25.50 tons	12
Age of vessel	14.8 years	13
Year vessel built	1956	13

Source: Hawaii Opinion, H-83-11C.

OWNERSHIP AND VESSEL FINANCING

The predominant form of ownership for the longline respondents was that of a sole proprietorship. Of the thirteen longline respondents, eight, representing 62% of total, operated as sole proprietorships. The remaining five longline respondents were distributed amongst partnership, corporate and other forms of ownership.

TABLE III-B

Vessel Ownership for Longline Respondents

	Respondents Providing Data	Distribution Of Respondents
Sole Proprietorship	8	61.5%
Partnership	1	7.7
Corporation	2	15.4
Other	2	15.4

Source: Hawaii Opinion, H-83-11C.

The form of ownership generally affects the method of financing used for the vessels, inasmuch as sole proprietorships and partnerships generally rely on personal and investor financing, respectively. Table III-C indicates that of the thirteen respondents, 62% indicated that they had used personal funds to finance a portion of the vessel costs, and 85% had used funds from other investors. Funds derived from a bank loan were used for 46% of the vessels. Government guaranteed loans were used for only two

vessels representing 15% of the total. According to Hawaii Opinion's summary, the distribution of funds used to finance the cost of a vessel indicates a mean of 47% of the funds being derived from personal resources and 45% from loans provided by banks. It is presumed that the remaining 8% is derived from other investors, government guaranteed loans, and/or other sources.

TABLE III-C

Method of Financing for Longline Respondents(1)

	Respondents Providing Data	Distribution Of Respondents
Personal Funds	8	61.5%
Other Investors	11	84.6%
Bank Loan	6	46.2%
Government Guaranteed Loan	2	15.4%
Other	1	7.7%

(1) Responses reflect multiple methods of financing.

Source: Hawaii Opinion, H-83-11C.

PURCHASE PRICE AND ESTIMATE OF CURRENT VALUE OF VESSEL

Table III-D presents a summary of the mean purchase value and estimated current value of longline vessels. The table also includes the computed standard error of the mean and the number of respondents. The standard error of the mean is used to estimate the population mean at a 50.0% confidence interval. The upper and lower limits of the interval represent an estimate of the upper and lower quartiles of a distribution of sample means drawn from the population of longline fishermen. There is a fifty percent (50%) likelihood that the unknown population mean will lie within the interval. There is a twenty five percent (25%) likelihood that the population mean is below the lower limit, and a similar likelihood that it is above the upper limit.

TABLE III-D

MEAN AND 50% CONFIDENCE INTERVAL
PURCHASE PRICE AND ESTIMATED CURRENT VALUE OF VESSEL
FOR ALL LONGLINE RESPONDENTS

	Mean	Std Error of Mean	Est. Mean at 50.0% Conf. Lower Limit	Upper Limit	Responses
Purchase Price of Boat.....	$94,537	38,973	$67,256	$121,818	11
Current Value of Boat.....	170,318	46,964	137,444	203,193	11

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

Table III-D indicates that the typical longline vessel required an initial capital investment of just under $100,000, and that respondents estimate that the current value of the vessels have appreciated. The mean purchase price of the long line

vessels is $94,537 with the estimated mean at the lower and upper limits of the 50% confidence intervals $67,256 and $121,818, respectively. The mean estimated value of the long line vessels is $170,318 with the estimated mean at the lower and upper limits of the 50% confidence intervals $137,318 and $203,193, respectively. The rate of change between the mean purchase price and the mean estimated current value of the vessels is 4.00% annually. The 4% rate of change is less than the rate of inflation, and suggest that the "real" value of the vessels, after considering the impact of inflation, has actually been depreciating.

TRIP ANALYSIS

Table III-E indicates that during a typical month the longline respondents made 2.77 trips per month with an average duration of 6.19 days per trip. Multiplying the average number of trips per month by the average duration of the typical trip indicates that on the average 206 days annualy were spent at sea, representing 56% of the year. The estimated mean at the lower limit of the 50% confidence interval indicates an average of 2.59 trips per month lasting 5.89 days per trip, representing 183 days at sea per year or 50% of the year. The estimated mean at the upper limit indicates an average of 2.95 trips per month lasting 6.49 days per trip, representing 230 days at sea per year or 63% of the year.

TABLE III-E

TRIP ANALYSIS
FOR ALL LONGLINE RESPONDENTS

	Mean	Standard Error of Mean	Est. Mean at 50.0% Conf. Lower Limit	Upper Limit	Responses
Number of Fishing Trips Average Month	2.77	.26	2.59	2.95	13
Duration of Fishing Trip (days)	6.19	.43	5.89	6.49	13
Days at Sea Per Year	205.78		183.22	229.61	

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

CAPITAL, FIXED AND VARIABLE EXPENSES

Table III-F presents summary statistics for capital, fixed and variable expenses indicated by longline respondents. The data indicate that total capital, fixed and variable cost of the respondents averaged $170,200. Capital and fixed expenses represented $24,450, or 14.4% of the total, and variable expenses represented $145,800, or 85.6% of the total. The estimated mean for total capital, fixed, and variable expenses at the 50.0% confidence interval indicated a lower limit of $139,500 and an upper limit of $200,900.

TABLE III-F

MEAN AND 50% CONFIDENCE INTERVAL
CAPITAL, FIXED AND VARIABLE EXPENSES
FOR ALL LONGLINE RESPONDENTS

	Mean	Standard Error of Mean	Est. Mean at Lower Limit	50.0%Conf. Upper Limit	Responses
Capital Expenses and Fixed Expenses:					
Boat Mortgage Paid in 1981	$16,456	844	$15,863	$17,049	10
Other Loans Paid in 1981	4,556	2,892	2,514	6,597	9
Licenses and Fees	2,241	1,482	1,187	3,294	8
Accounting and Bookkeeping	1,182	397	897	1,467	7
Sub Total	$24,434		$20,461	$28,408	
Variable Expenses					
Repairs					
Engine	$10,929	3,114	8,693	13,164	7
Hull	4,413	663	3,941	4,884	8
Electronic	919	316	694	1,144	8
Fish Equipment	4,671	1,218	3,797	5,546	7
Sub Total	$20,931		$17,125	$24,738	
Fuel and Oil	$11,561	3,114	$9,363	$13,760	9
Fishing Gear	8,871	663	8,395	9,348	7
Bait	12,798	316	12,575	13,020	10
Ice	4,692	1,218	3,836	5,548	10
Food	8,321	2,752	6,386	10,256	10
Auction and Unloading Fees	21,390	3,805	18,479	24,301	4
Sub Total	$67,633		$59,034	$76,232	
Share of Fish Paid to Crew and Captain(1)	$57,200	18,701	$42,894	$71,506	4
TOTAL VARIABLE EXPENSES	$145,764		$119,052	$172,476	
TOTAL CAPITAL, FIXED AND VARIABLE EXPENSES	$170,199		$139,513	$200,884	

(1) The share of fish paid to crew and captain is reported in the above table as a wage that does not vary relative to revenue.

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

VARIABLE EXPENSES PER DAY AT SEA

Table III-G presents the estimated variable expenses per day at sea based on the annual variable costs and the estimated days at sea. The mean variable expenses are estimated to be $708 per day at sea. The mean at the lower and upper limits of the 50% confidence intervals are estimated to be $650 and $751 per day at sea, respectively.

The analysis presented in Table III-G indicates that repairs account for 14% of the total variable costs reflecting both the relative age of the sampled vessels (15 years), and the fact that going to sea is rough on vessels. The average fuel and oil cost represents 8% of total variable costs. Gear costs represent 6% of total variable costs. Bait and ice represent a total of 12%, and auction and unloading fees represent 15% of total variable costs. The share of fish paid to crew and captain, representing 39% of variable cost, is reported in the table as a wage that does not vary relative to revenue.

TABLE III-G

VARIABLE EXPENSE ANALYSIS PER DAY AT SEA
FOR ALL LONGLINE RESPONDENTS

	Mean	Est. Mean at 50.0% Conf. Lower Limit	Upper Limit
Repairs:			
Engine	$53.11	$47.44	$57.33
Hull	21.44	21.51	21.27
Electronic	4.46	3.79	4.98
Fish Equipment	22.70	20.72	24.15
Sub Total	$101.72	$93.46	$107.74
Fuel and Oil	$56.18	$51.10	$59.93
Fishing Gear	43.11	45.82	40.71
Bait	62.19	68.63	56.70
Ice	22.80	20.93	24.16
Food & Provisions	40.44	34.85	44.67
Auction and Unloading Fees	103.95	100.86	105.84
Sub Total	$328.68	$322.20	$332.01
Share of Fish Paid to Crew and Captain(1)	$277.97	$234.11	$311.43
TOTAL VARIABLE EXPENSES	$708.37	$649.77	$751.18

(1) The share of fish paid to crew and captain is reported in the above table as a wage that does not vary relative to revenue.

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

BREAKEVEN AND RETURN ON INVESTMENT ANALYSIS

Since only two of the longline respondents provided revenue data, the breakeven and return on investment analysis, summarized in this section, makes the a priori assumption that the volume of fish caught and the resulting revenues earned are primarily dependent on the time spent at sea. In making this assumption, it is acknowledged that the volume weight is also dependent on other variables, such as the amount of gear used, the intensity of fishing effort, and the skill of the captain. These variables are not considered in the analysis.

Breakeven Analysis

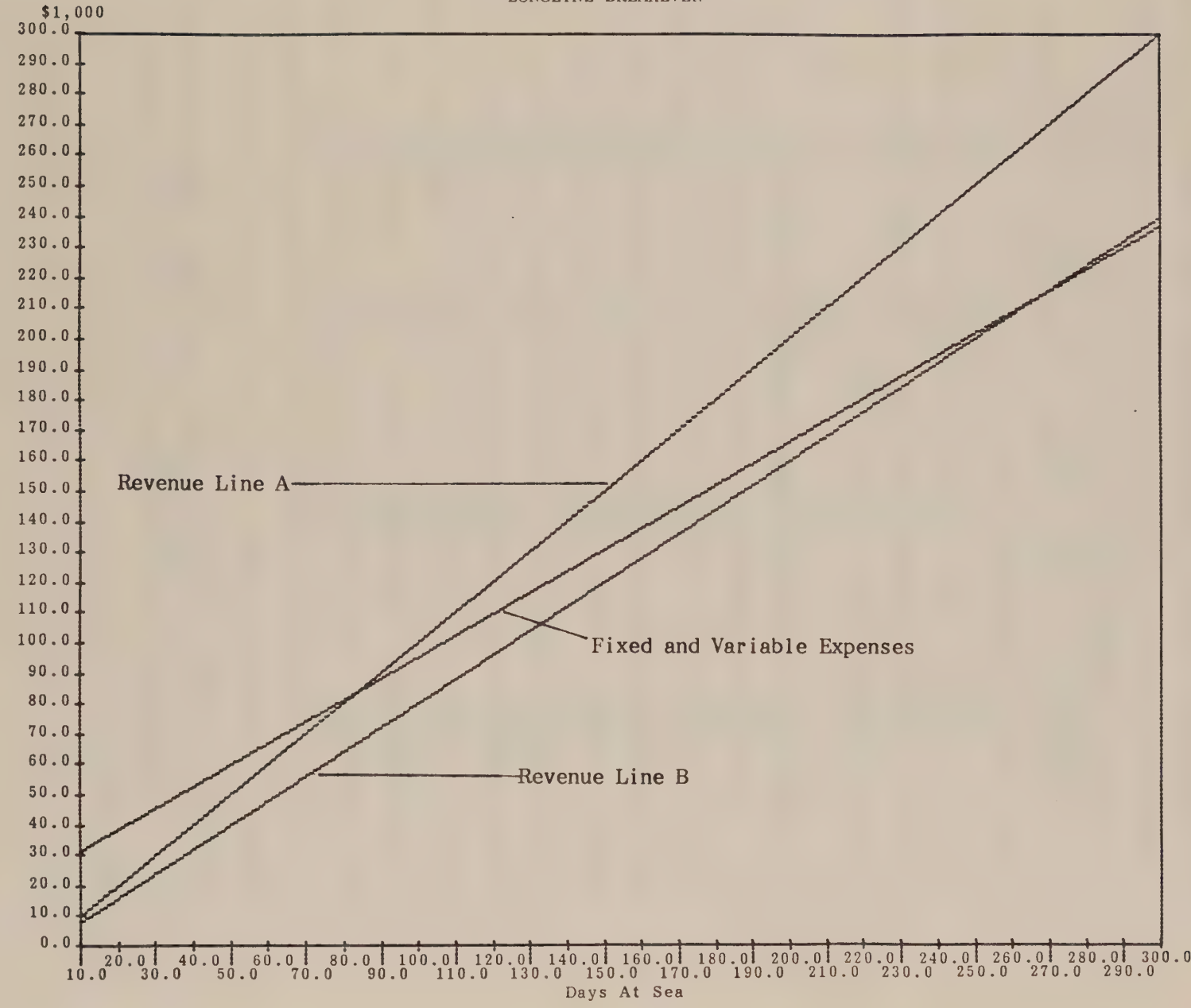
Breakeven analysis is based on relationships between costs and revenues and is useful in determining at which point revenues will cover total costs. Two sets of analysis were prepared. The first set is based on the linear relationship between expenses and revenues. The second set is based on the estimated volume weight of fishing activity necessary to cover total costs, assuming different periods of fishing activity ranging from one day to 300 days at sea.

Breakeven Analysis Depicting Revenues and Expenses

Illustration III-A is a graph showing the linear relationship between total expenses relative to the revenues that would be derived based on different assumptions regarding average daily catch rates and average price per pound. The graph illustrates the impact of a 25% change in either the average daily catch or the average price of fish per pound.

ILLUSTRATION III-A

LONGLINE BREAKEVEN



"Revenue Line A" assumes revenues of $800 per day at sea and "Revenue Line B" assumes revenues of $1,000 per day. The breakeven analysis depicted in Illustration III-A indicates that Revenue Line B would be profitable after approximately 85 days at sea, while Revenue Line A would not be profitable until after approximately 215 days at sea. The analysis illustrates the sensitivity of the effort required to break even relative to the factors determining average revenue per trip. The principal factors are the volume weight of fish caught per day and the average price per pound of fish sold.

Analysis Depicting Average Catch to Breakeven

Table III-H summarizes and Illustration III-B depicts a graphic plotting of the breakeven analysis for the mean value of all longline responses and the estimated means at the 50% confidence interval based on an assumed average price to the seller of $2.00 per pound. The analysis computes the average daily catch required to breakeven per day at sea for periods of 10 to 300 days annually. As would be expected, the fixed costs require a relatively high breakeven point for relatively short annual periods at sea. The breakeven point decreases at a declining rate as relative portion of the year spent at sea increases. Based on the mean value, after 100 days per year at sea, the breakeven point is 476 pounds per day at sea, after 200 days at sea it decreases to 415 pounds per day, and after 300 days it is 395 pounds per day.

TABLE III-H

POUNDS OF FISH REQUIRED TO BREAKEVEN AT $2.00 PER POUND
BASED ON AN ANALYSIS OF ALL LONGLINE RESPONDENTS

Days At Sea Per Year	Pounds Per Day At Sea	50% Confidence Interval	
	Mean Value $2.00/lb.	Lower Lmt $2.00/lb.	Upper Lmt. $2.00/lb.
10	1,576	1,348	1,796
20	965	836	1,086
30	761	666	849
40	660	581	731
50	599	529	660
60	558	495	612
70	529	471	579
80	507	453	553
90	490	439	533
100	476	427	518
110	465	418	505
120	456	410	494
130	448	404	485
140	441	398	477
150	436	393	470
160	431	389	464
170	426	385	459
180	422	382	455
190	418	379	450
200	415	376	447
210	412	374	443
220	410	371	440
230	407	369	437
240	405	368	435
250	403	366	432
260	401	364	430
270	399	363	428
280	398	361	426
290	396	360	425
300	395	359	423

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

ILLUSTRATION III-B

BREAKEVEN ANALYSIS OF LONGLINE RESPONDENTS

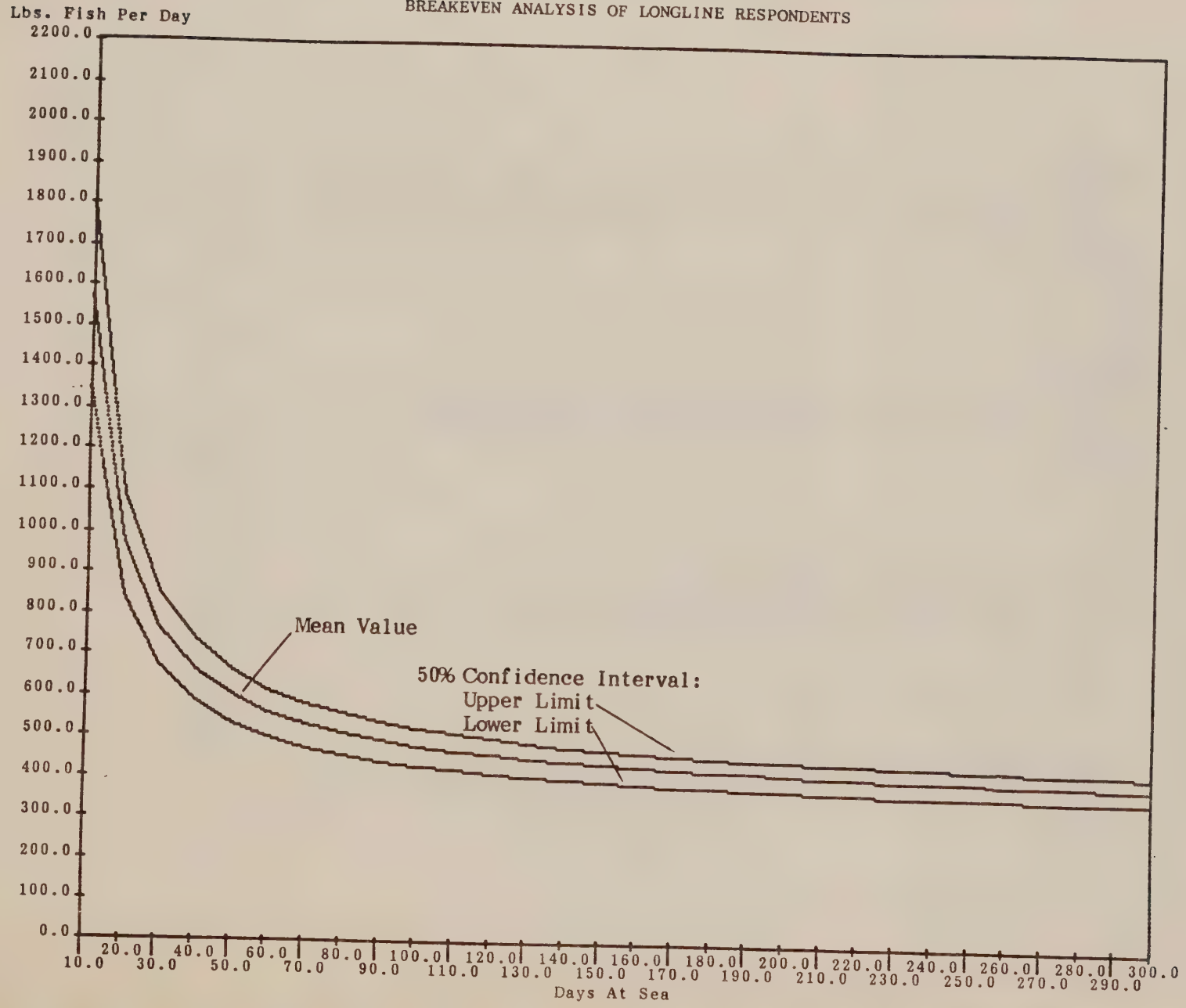


Table III-I summarizes and Illustration III-C depicts a graphic plotting of the breakeven analysis based on the mean of all longline responses and assumes average prices to the seller of $1.50, $2.00, and $2.50 per pound of fish. The analysis computes the average daily catch required to break even for periods ranging between 10 and 300 days at sea annually. As would be expected, the fixed costs require a relatively high breakeven point for relatively short annual periods at sea, and the breakeven point decreases at a declining rate as the days per year spent at sea increases. Also, as would be expected, there is an inverse relationship between average price per pound and the volume weight of catch required to break even. For example, a 25% decrease in price from $2.00 to $1.50 per pound results in a 33% increase in the breakeven point, while a 33% increase in price from $1.50 to $2.00 results in a 25% decrease in the breakeven point.

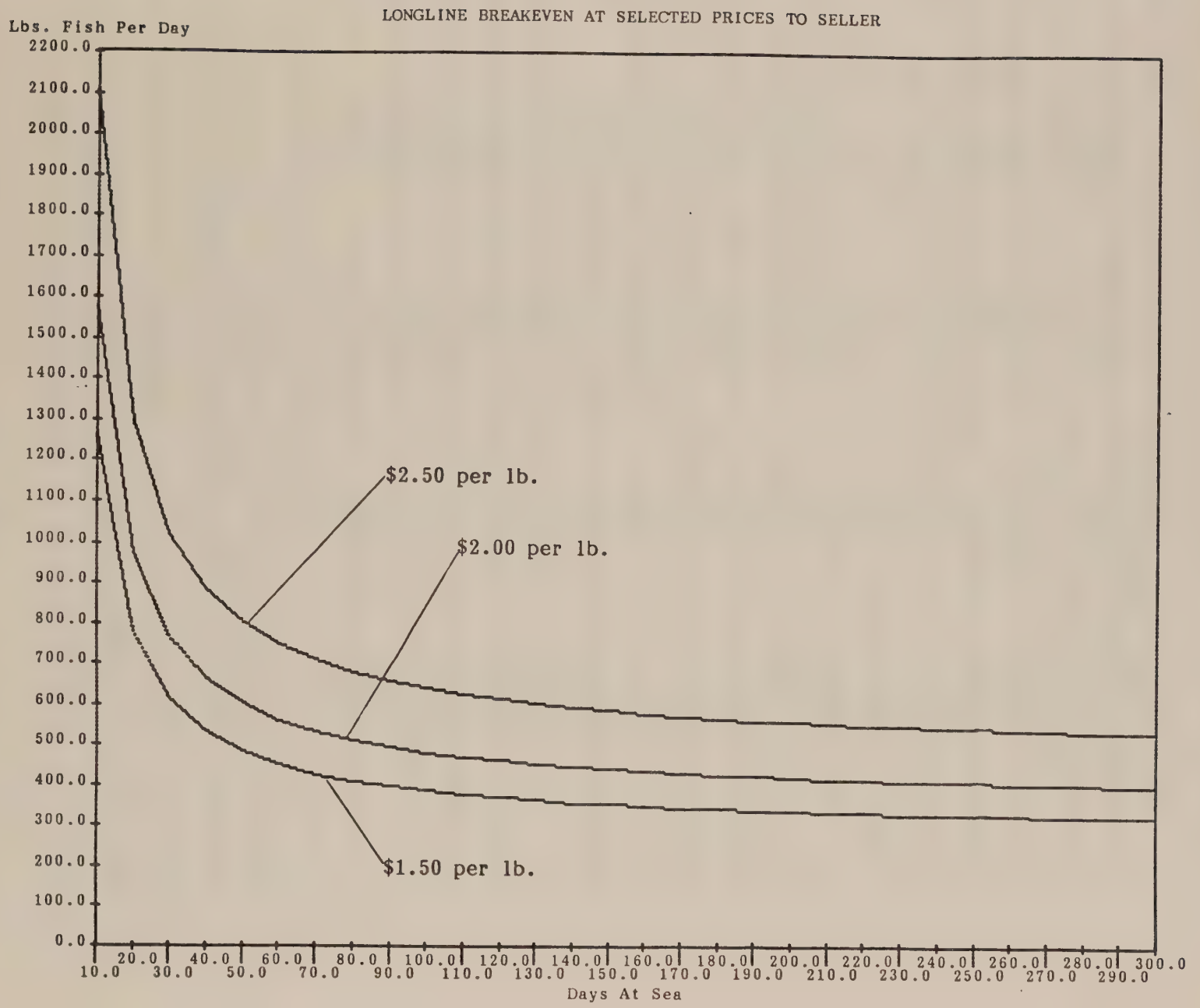
TABLE III-I

POUNDS OF FISH REQUIRED TO BREAKEVEN AT SELECTED PRICES
BASED ON THE MEAN FOR ALL LONGLINE RESPONDENTS

Days At Sea Per Year	Pounds Per Day At Sea		
	$1.50/lb.	$2.00/lb.	$2.50/lb.
10	2,101	1,576	1,261
20	1,287	965	772
30	1,015	761	609
40	879	660	528
50	798	599	479
60	744	558	446
70	705	529	423
80	676	507	406
90	653	490	392
100	635	476	381
110	620	465	372
120	608	456	365
130	598	448	359
140	589	441	353
150	581	436	349
160	574	431	344
170	568	426	341
180	563	422	338
190	558	418	335
200	554	415	332
210	550	412	330
220	546	410	328
230	543	407	326
240	540	405	324
250	537	403	322
260	535	401	321
270	533	399	320
280	530	398	318
290	528	396	317
300	527	395	316

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

ILLUSTRATION III-C



Return on Investment Analysis

The rate of return required by investors may be thought of as being comprised of three parts: the risk-free rate, a premium for business risk, and a premium for financial risk. The risk-free rate is the rate of return that could be earned on United States Treasury securities. The premium for business risk is attributable to the possible fluctuation of future operating income, and the premium for financial risk is attributable to the fluctuation of future earnings available to the proprietor, partners, or shareholders.

The analysis of return on initial investment is to estimate the volume weight of fishing activity necessary to cover an assumed 25% return on initial investment, and the total fixed, capital and variable costs assuming different periods of fishing activity ranging from one day to 300 days at sea. Two sets of analysis were prepared and are briefly discussed below.

Table III-J summarizes and Illustration III-D depicts a graphic plotting of the return on initial investment analysis for the mean value of all longline responses and the estimated means at the 50% confidence interval based on an assumed 25% rate of return on initial investment and average price to the seller of $2.00 per pound. The analysis computes the average catch per day at sea required to achieve a 25% return for periods of 10 to 300 days annually. As would be expected, the catch required to achieve a 25% return on initial investment decreases at a declining rate as the days per year spent at sea increases. Based on

TABLE III-J

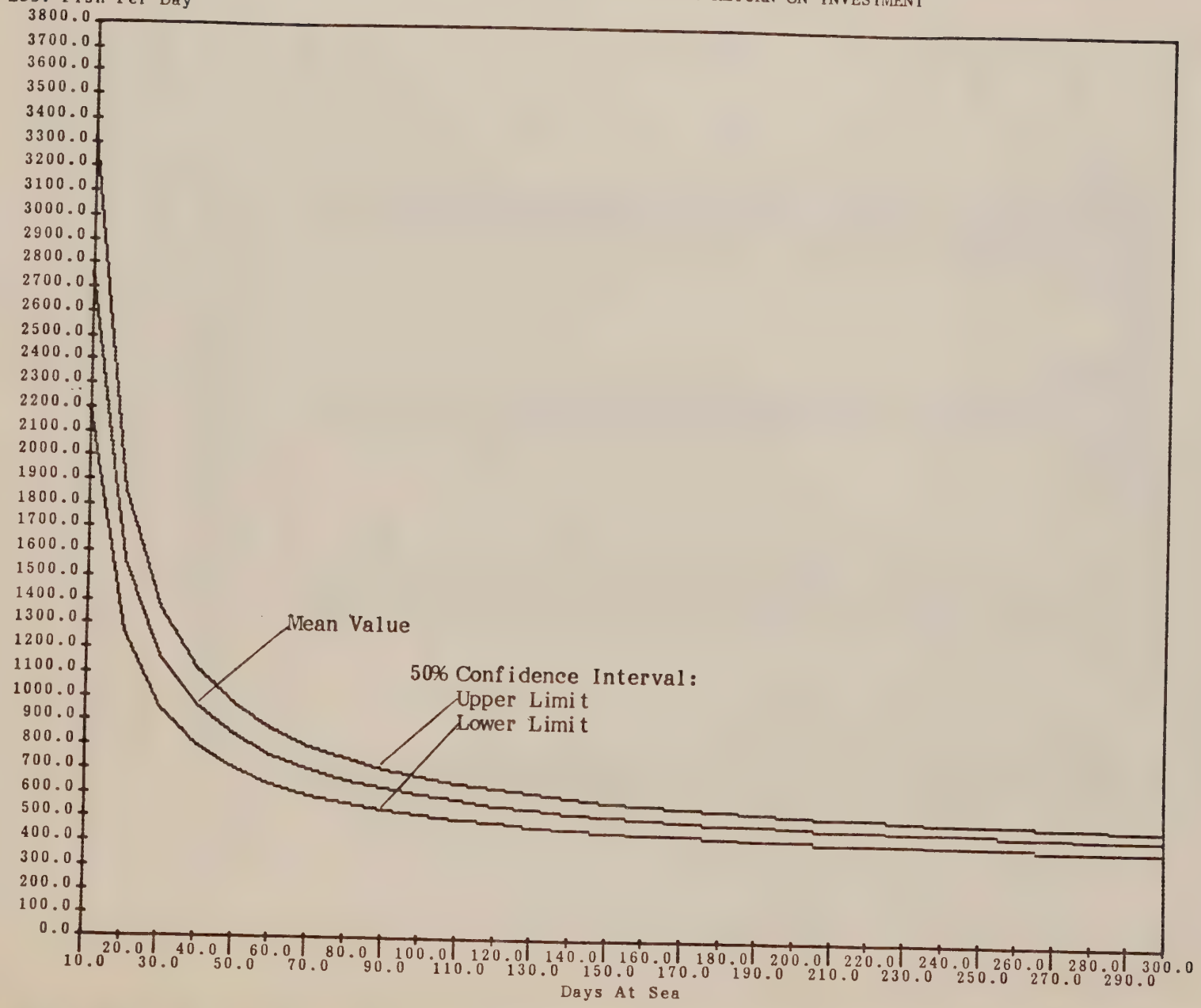
POUNDS OF FISH REQUIRED TO ACHIEVE A 25% RETURN ON INVESTMENT BASED ON AN ANALYSIS OF ALL LONGLINE RESPONDENTS

Days At Sea Per Year	Pounds Per Day At Sea: Mean Value at 25% ROI $2.00/lb.	50% Confidence Interval: Lower Lmt. at 25% ROI $2.00/lb.	50% Confidence Interval: Upper Lmt. at 25% ROI $2.00/lb.
10	2,757	2,189	3,318
20	1,556	1,257	1,847
30	1,155	946	1,357
40	955	791	1,111
50	835	698	964
60	755	636	866
70	697	591	796
80	655	558	743
90	621	532	703
100	594	511	670
110	573	494	643
120	554	480	621
130	539	468	602
140	526	458	586
150	514	449	572
160	504	441	560
170	496	435	549
180	488	428	539
190	481	423	530
200	474	418	523
210	469	414	516
220	463	410	509
230	459	406	504
240	454	403	498
250	450	399	493
260	447	397	489
270	443	394	485
280	440	391	481
290	437	389	477
300	434	387	474

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

ILLUSTRATION III-D

LONGLINE ANALYSIS BASED ON A 25% RETURN ON INVESTMENT



the mean value, after 100 days per year at sea a 25% return on initial investment is achieved if the average daily volume weight of fish caught equals or exceeds 594 pounds per day at sea. After 200 days at sea the volume weight decreases to 474 pounds per day, and after 300 days it is 434 pounds per day.

Table III-K summarizes and Illustration III-E depicts a graphic plotting of the average daily catch required to achieve a 25% return on initial investment analysis based on the mean of all longline responses and assumes average prices to the seller of $1.50, $2.00, and $2.50 per pound of fish. As would be expected, the catch required decreases at a declining rate as the days per year spent at sea increases. Also, as would be expected, there is an inverse relationship between average price per pound and the volume weight of catch required to achieve a 25% return. A 25% decrease in price from $2.00 to $1.50 per pound results in a 33% increase in the volume weight required to achieve a 25% return, and a 33% increase in price from $1.50 to $2.00 results in a 25% decrease in the volume weight required.

TABLE III-K

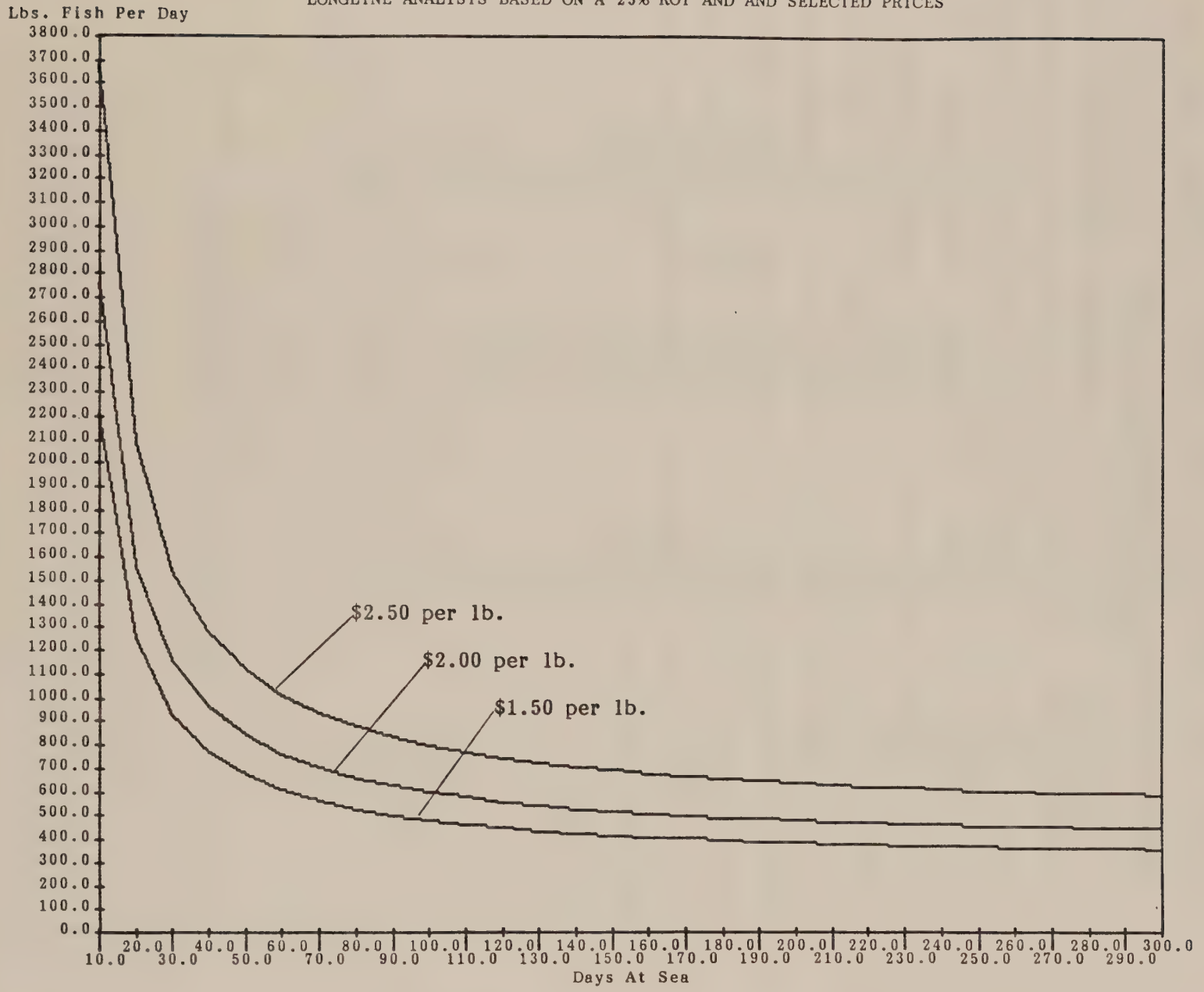
AVERAGE DAILY CATCH REQUIRED
TO ACHIEVE A 25% RETURN ON INVESTMENT AT SELECTED PRICES
BASED ON THE MEAN FOR ALL LONGLINE RESPONDENTS

Days At Sea Per Year	Pounds Per Day At Sea		
	$1.50/lb.	$2.00/lb.	$2.50/lb.
10	3,676	2,757	2,206
20	2,074	1,556	1,245
30	1,540	1,155	924
40	1,273	955	764
50	1,113	835	668
60	1,006	755	604
70	930	697	558
80	873	655	524
90	828	621	497
100	793	594	476
110	764	573	458
120	739	554	444
130	719	539	431
140	701	526	421
150	686	514	412
160	672	504	403
170	661	496	396
180	650	488	390
190	641	481	385
200	632	474	379
210	625	469	375
220	618	463	371
230	612	459	367
240	606	454	363
250	600	450	360
260	595	447	357
270	591	443	355
280	587	440	352
290	583	437	350
300	579	434	347

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

ILLUSTRATION III-E

LONGLINE ANALYSIS BASED ON A 25% ROI AND AND SELECTED PRICES



Breakeven Relative to Return on Investment

The relationship between the volume weight required to achieve the breakeven point and the volume weight required to achieve a 25% return on investment is summarized in Table III-L and depicted in Illustration III-F. The analysis is based on an assumed 25% rate of return on initial investment and average price to the seller of $2.00 per pound. The difference between the volume weight required to breakeven and that which is required to achieve a 25% return on initial investment decreases at a declining rate as the days per year spent at sea increases. After 100 days per year at sea, an additional 118 pound per day would be required in order to increase the level of profitablity from the breakeven point to a level which achieves a 25% return on the initial capital investment. This decreases to 59 pounds per day at 200 days per year, and 39 pounds per day at 300 days per year.

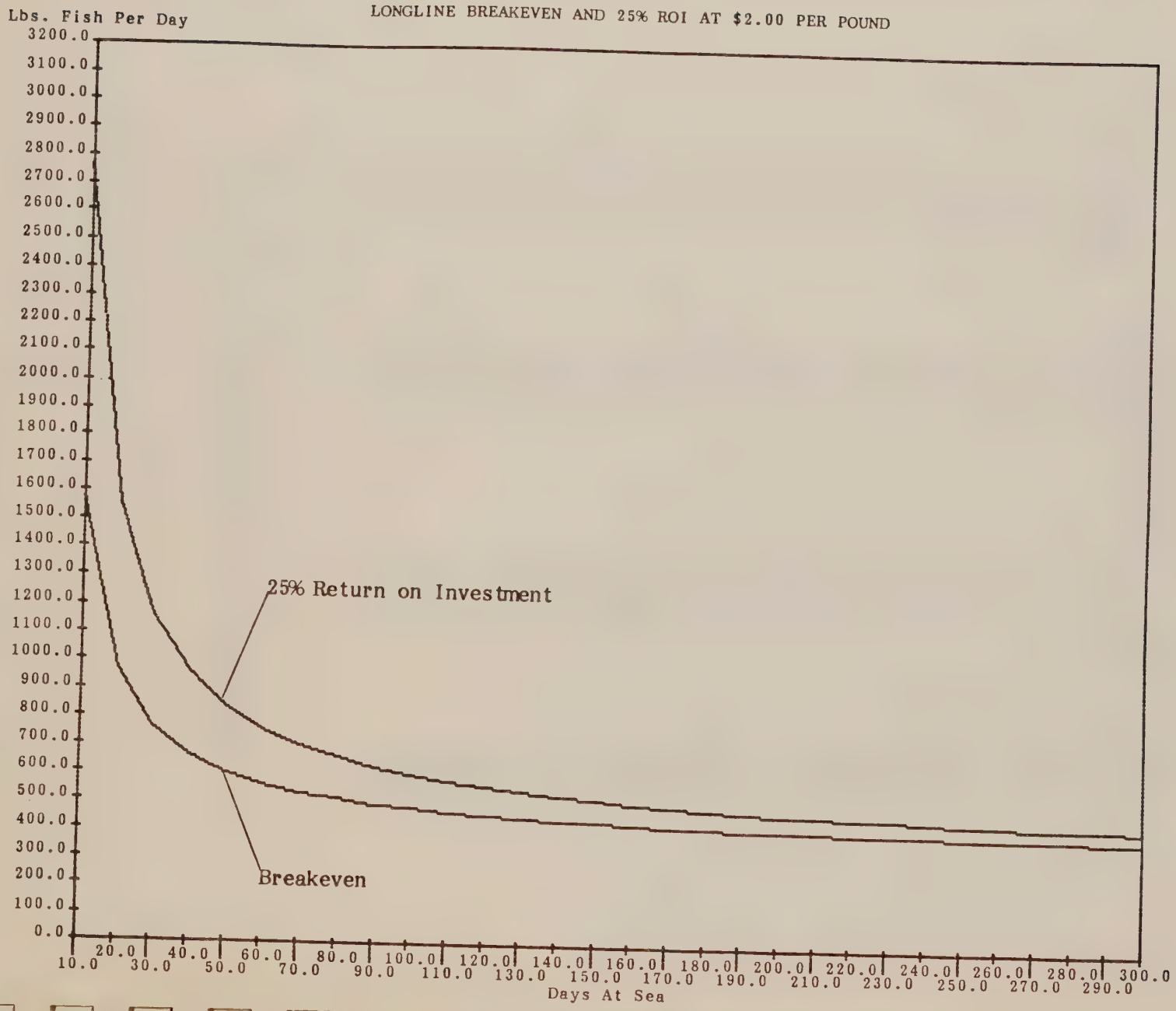
TABLE III-L

AVERAGE DAILY CATCH REQUIRED TO BREAKEVEN
AND TO ACHIEVE A 25% RETURN ON INVESTMENT AT $2.00 PER POUND
BASED ON THE MEAN FOR ALL LONGLINE RESPONDENTS

Days At Sea Per Year	Pounds Per Day At Sea — Volume Weight Required To: Breakeven	Achieve A 25% ROI	ROI Less Breakeven
10	1,576	2,757	1,181
20	965	1,556	591
30	761	1,155	394
40	660	955	295
50	599	835	236
60	558	755	197
70	529	697	169
80	507	655	148
90	490	621	131
100	476	594	118
110	465	573	107
120	456	554	98
130	448	539	91
140	441	526	84
150	436	514	79
160	431	504	74
170	426	496	69
180	422	488	66
190	418	481	62
200	415	474	59
210	412	469	56
220	410	463	54
230	407	459	51
240	405	454	49
250	403	450	47
260	401	447	45
270	399	443	44
280	398	440	42
290	396	437	41
300	395	434	39

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

ILLUSTRATION III-F



IV - HANDLINE FLEET ANALYSIS

OVERVIEW

The handline fleet survey conducted by Hawaii Opinion interviewed the captains and owners. The sample for the handline survey was provided by NMFS staff and was drawn from the state's listing of boat owners holding commercial fishing licenses. A total of 644 names and addresses were drawn, using a systematic skip to yield a field of 100 successful interviews. This was done since it was anticipated that many of the names would appear as duplicates (due to multiple boat ownership and outdated records) and that many owners would not be active handliners, since the commercial license file included longline, troll, and net fishing gear types as well as handline.

The initial screening of prospective handline respondents was by means of a short mailout survey. This instrument asked whether or not the respondents were active handline fishermen and updated telephone and address data. Respondents who indicated that they were not handliners were eliminated from the sample.

The handline survey was conducted between November 15, 1982 and January 18, 1983. Interviews were conducted on weekdays, weekends, day or evening, at the convenience of the respondents. Up to four attempts were made to contact prospective respondents in the sample.

Of the 100 interviews completed, 24 were based on Oahu, 50 on the island of Hawaii, 17 on Kauai, and 9 on Maui. Of the original 644 names, there were 28 potential respondents who refused interviews or were not available, and 178 that could not be contacted. It is not known to what extent, if any, the non-respondents introduced an element of bias in the survey results. The following summarizes the data collection effort:

644 total sample

100 interviews completed

202 duplicate owner names

136 not active handliners

28 known handliners, but refused or not available for interviews

178 unable to contact

FLEET DESCRIPTION

Based on the surveys completed, Table IV-A summarizes selected attributes of the handline fleet. As indicated, the handline fleet vessels have a mean length of 24 feet. The mean age of the vessels in mid-1982 was 4.4 years, and the mean net tonnage was 2.3 tons.

TABLE IV-A

Selected Attributes of the Handline Fleet

		Respondents Providing Data
Length of boat	23.9 feet	100
Age of Vessel	4.4 years	100
Net Tonnage	2.3 tons	100

Source: Hawaii Opinion, H-83-11C.

OWNERSHIP AND VESSEL FINANCING

Table IV-B indicates that the predominant form of ownership for the handline respondents was that of a sole proprietorship. Of the 100 handline respondents, 92, representing 92% of total, operated as sole proprietorships. The remaining eight handline respondents were distributed amongst partnership, corporate and other forms of ownership.

TABLE IV-B

Vessel Ownership for Handline Respondents

	Respondents Providing Data	Distribution Of Respondents
Sole Proprietorship	92	92.0%
Partnership	4	4.0
Corporation	3	3.0
Other	1	1.0

Source: Hawaii Opinion, H-83-11C.

The form of ownership generally affects the method of financing used for the vessels, inasmuch as sole proprietorships and partnerships generally rely on personal and investor financing, respectively. Table IV-C indicates that of the 100 respondents, 80% indicated that they had used personal funds to finance a portion of the vessel costs, and only 1% had used funds from other investors. Funds derived from a bank loan were used by 25% of the vessels. Government guaranteed loans were used by only three vessels representing 3% of the total.

TABLE IV-C

Method of Financing for Handline Respondents(1)

	Respondents Providing Data	Distribution Of Respondents
Personal Funds	80	80.0%
Other Investors	1	1.0%
Bank Loan	25	25.0%
Government Guaranteed Loan	3	3.0%
Other	16	16.0%

(1) Responses reflect multiple methods of financing.

Source: Hawaii Opinion, H-83-11C.

PURCHASE PRICE AND ESTIMATE OF CURRENT VALUE OF VESSEL

Table IV-D presents a summary of the mean purchase value and estimated current value of handline vessels. The table also includes the computed standard error of the mean and the number of respondents. The standard error of the mean is used to estimate the population mean at a 50.0% confidence interval. The upper and lower limits of the interval represent an estimate of the upper and lower quartiles of a distribution of sample means drawn from the population of handline fishermen. There is a fifty percent (50%) likelihood that the unknown population mean will lie within the interval. There is a twenty five percent (25%) likelihood that the unknown population mean is below the lower limit, and a similar likelihood that it is above the upper limit.

TABLE IV-D

MEAN AND 50% CONFIDENCE INTERVAL
PURCHASE PRICE AND ESTIMATED CURRENT VALUE OF VESSEL
FOR ALL HANDLINE RESPONDENTS

	Sample Mean	Std Error of Mean	Est. Mean at 50.0% Conf. Lower Limit	Upper Limit	Responses
Purchase Price of Boat.....	$17,573	2,864	$15,628	$19,518	97
Current Value of Boat.....	24,440	4,170	21,608	27,271	96

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

The table reflect the handline fleet being comprised largely of smaller vessels as indicated by the mean purchase price of the handline vessels is $17,573. The estimated mean at the lower and upper limits of the 50% confidence intervals are $15,628 and $21,608, respectively. The mean estimated value of the handline vessels is $24,440, and the estimated mean at the lower and upper limits of the 50% confidence intervals $21,608 and $27,271, respectively. Based on the 4.4 year average age of all vessels, the difference between the purchase price and estimated current value reflects 7.79% annual rate of change. This rate of change approximates the average rate of inflation during the period 1978-81.

TRIP ANALYSIS

The analysis of the trip related data indicates that the handliners typically made frequent trips of less than one day duration. Table IV-E indicates that during the typical month, the handline respondents made 9.02 trips per month with an average duration of 17.5 hours per trip. This infers that an average of 108 trips were made annually (trips per month x 12 months). Based on the average duration of each trip, an average of 1,894 hours annually were spent at sea. The estimated mean at the lower limit of the 50% confidence interval indicates an average of 8.56 trips per month lasting 15.8 hours per trip, representing 103 trips per year and 1,623 hours annually. The estimated mean at the upper limit of the 50% confidence interval indicates an average of 9.48 trips per month lasting 19.2 hours per trip, representing 114 trips per year and 2,184 hours annually.

TABLE IV-E

TRIP ANALYSIS
FOR ALL HANDLINE RESPONDENTS

	Sample Mean	Standard Error of Mean	Est. Mean at 50.0% Conf. Lower Limit	Upper Limit	Responses
Number of Fishing Trips Average Month	9.02	.67	8.56	9.48	97
Duration of Fishing Trip (days)	.73	.10	.66	.80	99
Trips per Year	108.24		102.72	113.76	
Hours at Sea Per Year	1,896		1,627	2,184	

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

CAPITAL, FIXED AND VARIABLE EXPENSES

Table IV-F presents summary statistics for capital, fixed and variable expenses indicated by handline respondents. The table also includes the computed standard error of the mean and the number of respondents. A perspective concerning the distribution of responses is provided by the estimated mean at a 50.0% confidence interval which represents the lower and upper quartiles of the distribution.

The total mean capital, fixed and variable expenses were $15,437. Capital and fixed expenses represented $2,192, or 14.2% of the total, and variable expenses represented $13,246, or 85.4% of the total. The estimated mean for total capital, fixed, and variable expenses at the 50.0% confidence interval indicated a lower limit of $12,908 and an upper limit of $17,967.

TABLE IV-F

MEAN AND 50% CONFIDENCE INTERVAL
CAPITAL, FIXED AND VARIABLE EXPENSES
FOR ALL HANDLINE RESPONDENTS

	Sample Mean	Standard Error of Mean	Est. Mean at Lower Limit	50.0%Conf. Upper Limit	Responses
Capital Expenses and Fixed Expenses:					
Boat Mortgage Paid in 1981	$1,345	414	$1,064	$1,626	100
Trailer Mortgage Paid in 1981	20	20	6	34	99
Other Loans Paid in 1981	295	188	167	422	100
Licenses and Fees	161	67	116	207	98
Accounting and Bookkeeping	0	0	0	0	0
Boat Insurance	365	90	303	426	92
Trailer Insurance	5	3	3	7	90
Sub Total	$2,192		$1,661	$2,722	
Variable Expenses					
Repairs (1981):					
Engine	$1,014	238	853	1,175	99
Hull	269	75	218	320	99
Electronic	105	31	84	125	99
Fish Equipment	263	71	214	311	98
Sub Total	$1,650		$1,369	$1,931	
Fuel and Oil	$3,298	390	$3,033	$3,563	93
Fishing Gear	1,520	258	1,344	1,695	96
Bait	1,259	350	1,021	1,496	95
Ice	848	139	754	943	92
Food	846	172	729	962	86
Auction and Unloading Fees	1,252	435	957	1,548	78
Sub Total	$9,023		$7,838	$10,207	
Share of Fish Paid to Crew and Captain(1)	$2,573	785	$2,040	$3,106	80
TOTAL VARIABLE EXPENSES	$13,246	785	$11,247	$15,244	
TOTAL CAPITAL, FIXED AND VARIABLE EXPENSES	$15,437		$12,908	$17,967	

(1) The share of fish paid to crew and captain is reported in the above table as a wage that does not vary relative to revenue.

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

VARIABLE EXPENSES PER TRIP

Table IV-G presents the variable expenses per trip based on the annual variable costs, presented in Table IV-E, and the estimated trips annually, shown in the previous table. The mean variable expenses are estimated to total $122 per trip. The mean at the lower and upper limits of the 50% confidence intervals are estimated to total $109 per trip and $134 per trip, respectively.

TABLE IV-G

VARIABLE EXPENSE ANALYSIS PER TRIP
FOR ALL HANDLINE RESPONDENTS

	Sample Mean	Est. Mean at 50.0% Conf. Lower Limit	Upper Limit
Repairs:			
Engine	$9.37	8.30	10.33
Hull	2.48	2.12	2.81
Electronic	.97	.82	1.10
Fish Equipment	2.43	2.09	2.73
Sub Total	$15.24	13.33	16.98
Fuel and Oil	$30.47	29.53	31.32
Fishing Gear	14.04	13.09	14.90
Bait	11.63	9.94	13.15
Ice	7.84	7.34	8.29
Food	7.81	7.09	8.46
Auction and Unloading Fees	11.57	9.31	13.61
Sub Total	$83.36	76.31	89.72
Share of Fish Paid to Crew and Captain(1)	$23.77	$19.86	$27.30
TOTAL VARIABLE EXPENSES	$122.37	$109.49	$134.01

(1) The share of fish paid to crew and captain is reported in the above table as a wage that does not vary relative to revenue.

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

The analysis presented in Table IV-G indicates that repairs account for 12% of the total variable costs reflecting the fact that going to sea is rough on vessels. The average fuel and oil cost represents 25% of total variable costs. Gear costs represent 11% of total variable costs. Bait and ice represent a total of 13%, and auction and unloading fees represent 9% of total variable costs. The share of fish paid to crew and captain, representing 19% of variable cost, is reported in the table as a wage that does not vary relative to revenue.

COST-EARNINGS ANALYSIS

The analysis of sales was hampered by the non-response rate for questions concerning sales and weight of fish sold. Although all 100 of the respondents surveyed indicated that they had caught tuna, less than 50% responded to the questions related to sales. The non-response rate presented a serious degrees of freedom problem for testing models. A priori, one would hypothesize that the handline fleet in Hawaii is composed of many part-time and/ornon-commercial fishermen as well as some full-time fishermen. While the non-commercial fishermen may sell part of their catch to offset their costs, they do not typically engage in intensive fishing effort or fish on a regular basis. Seasonal fishing patterns may also be a problem. The hypothesis that the handline fleet is composed primarily of part-time and/or non-commercial fishermen is supported by the survey data which indicates that 56% of the handline respondents did not consider fishing to be their primary occupation and 59% had another occupation.

In order to analyze the statistical relationship of revenues and expenses, consideration was given to stratifying the data based on the type of fish caught on the last trip. This alternative was rejected since the last trip could not be concluded to be representative of the mix of fish caught annually. Rejection of this approach is based on the a priori hypothesis that as seasonal changes occur in both the price and/or the availability of a particular species of fish, the handline fishermen would adjust their fishing strategies accordingly. To the extent that sales data was provided by respondents, the data from respondents who sold tuna and/or bottom fish supports this hypothesis. The data indicates that of 50 respondents who reported sales for tuna and/or bottom fish, 26 (52%) sold both tuna and bottom fish, 15 (30%) sold only tuna, and 9 (18%) sold only bottom fish.

An alternative perspective, presented in Table IV-H, is the stratification of the data based on sales reported for 1981. The table presents selected data based on three strata: sales equal to or greater than $10,000; sales less than $10,000; and no sales data. The table also shows comparative data for all respondents.

The stratified data lends support to the hypothesis that the handliners are primarily part-time or non-commercial fishermen. Only 12 of the 52 respondents reporting sales data had sales greater than $10,000. Of the respondents who reported sales in excess of $10,000, 84% considered fishing to be their primary occupation compared to 39% of the respondents with sales less

TABLE IV-H

Selected Data Based on
Stratification of the Handline Respondents by Sales

	Sales Greater Than $10,000	Sales Less Than to $10,000	No Sales Data	All Respondents
Number of Observations	**12**	**40**	**48**	**100**
Boat Length (ft)	26.8	24.6	22.0	23.9
Boat Tonnage (tons)	4.1	2.7	1.5	2.3
Fish Trips per Month	13.20	6.76	9.8	9.0
Crew Size	2.2	2.1	2.0	2.1
Years Commercial Fish	8.75	7.70	14.20	10.9
% Fish Primary Occ.	83.7	38.5	25.0	44.0
Hours per Week Fish	60	34	35	38
Annual Income Index	5.8	2.0	2.8	4.8
% Another Occupation	33.3	62.5	62.5	59.0
Hours per Week Other Occupation	40.0	41.6	40.0	41.2
Total Sales Major Fish	$32,020	3,138	No Data	No Data
Total Expenses	28,239	8,881	11,360	No Data
Net Income (Loss) Sales less Expenses	$3,781	-5,743	NA	NA

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

than $10,000. Respondents with sales in excess of $10,000 averaged 60 hours per week fishing compared to an average of 34 hours per week for respondents with sales less than $10,000. Only 33% of the respondents who had sales in excess of $10,000 had a second job, compared to 63% for respondents with either sales below $10,000 or respondents who did not report sales. Also supporting the hypothesis that handliners are not commercial fishermen is the finding that the only group of handliners to achieve a positive earnings, based only on sales of major species, were those with sales over $10,000. This group represents only 25% of those who responded to the sales question and only 12% of the survey sample.

WEIGHT OF AVERAGE CATCH

Survey data concerning the weight of the average catch reported by respondents, shown in Table IV-I, indicates that respondents reporting higher levels of sales also reported relatively higher average catches. The sample mean for respondents indicating sales equal to or in excess of $10,000 is approximately 100% greater than the mean for respondents reporting sales less than $10,000.

TABLE IV-I

Average Weight of Catch
Reported by Handline Respondents
(Pounds)

	Sample Mean	Standard Deviation	Standard Error Of Mean	Range (High/Low)	Number of Responses
All Handline Respondents	215.9	206.4	29.5	975/25	49
Sales of $10,000 or More	375.0	357.9	160.1	975/50	5
Sales less then $10,000	186.3	142.1	30.3	500/35	22
No Sales/Sales Not Reported	209.3	213.9	45.6	950/25	22

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

BREAKEVEN AND RETURN ON INVESTMENT ANALYSIS

The breakeven and return on investment analysis, summarized in this section, makes the a priori assumption that the volume of fish caught and the resulting revenues earned are primarily dependent on the number of trips made annually. In making this assumption, it is acknowledged that the volume weight is also dependent on other variables, such as the amount of gear used, the intensity of fishing effort, and the skill of the captain. These variables are not considered in the analysis.

Breakeven Analysis

Breakeven analysis is based on relationships between costs and revenues and is useful in determining at which point revenues will cover total costs. The breakeven analysis presented in this section first considers the linear relationship between expenses

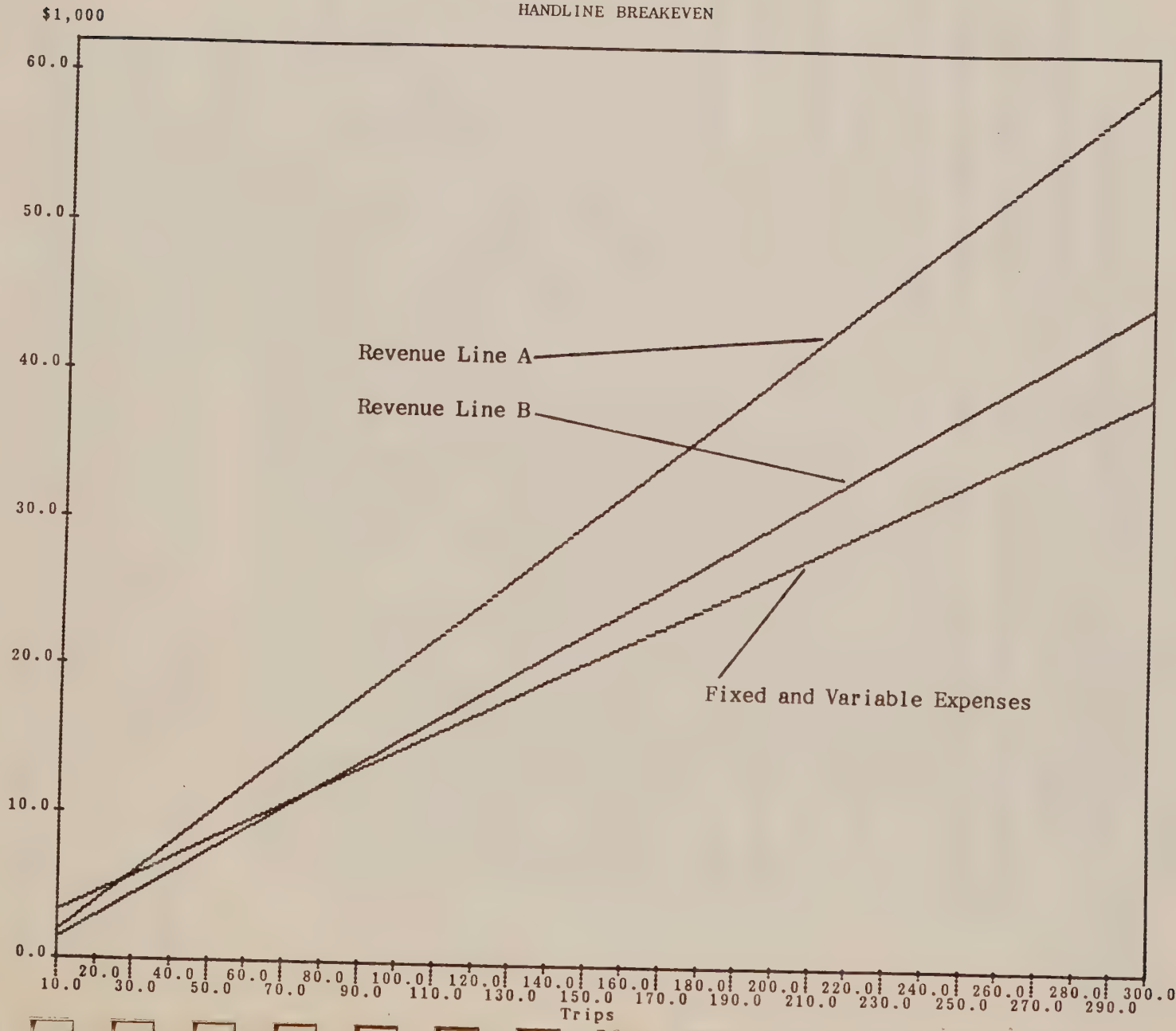
and revenues. The analysis then considers the volume weight of fishing activity necessary to cover total costs assuming different periods of fishing activity ranging from ten to 300 trips annually.

Breakeven Analysis Depicting Revenues and Expenses

Illustration IV-A is a graph showing the linear relationship between total expenses relative to the revenues that would be derived based on selected assumptions regarding average catch rates per trip and average price per pound. The graph illustrates the impact of increasing the value of the catch per trip by 33% from $150 per trip, "Revenue Line A," to $200 per trip, "Revenue Line B." Revenue Line A indicates that profitable fishing would be attained after approximately 75 trips per year, while Revenue Line B would be profitable after approximately 30 trips per year. The analysis indicates that a 33% increase in the revenue produced per trip would decrease the effort, measured in terms of trips, required to break even by approximately 45 trips or slightly over 60%. This illustrates the sensitivity of the effort required to break even relative to changes in the factors determining average revenue per trip. The principal factors are the volume weight of fish caught per trip the average catch and the average price per pound of fish sold.

ILLUSTRATION IV-A

HANDLINE BREAKEVEN



Analysis Depicting Average Catch to Breakeven

Table IV-J summarizes and Illustration IV-B depicts a graphic plotting of the breakeven analysis for the mean value of all handline responses and the estimated means at the 50% confidence interval based on an assumed average price to the seller of $2.50 per pound. The analysis computes the average catch per trip required to break even for 10 to 300 trips annually. As would be expected, the fixed costs require an increasing catch per trip for relatively fewer trips annually. The breakeven point decreases at a declining rate as the number of trips increases. Based on the mean value, after 60 trips per year, the breakeven point is 212 pounds per trip, after 90 trips it decreases to 158 pounds per trip, and after 120 trips it is 130 pounds per trip.

Table IV-K summarizes and Illustration IV-C depicts a graphic plotting of the breakeven analysis based on the mean of all handline responses and assumes average prices to the seller of $2.00, $2.50, and $3.00 per pound of fish. The analysis computes the average catch per trip required to break even for 10 to 300 trips annually. As would be expected, the breakeven point decreases at a declining rate as the number of trips per year increases. Also as would be expected, there is an inverse relationship between average price per pound and the volume weight of catch required to break even. For example, a 20% decrease in price from $2.50 to $2.00 per pound results in a 25% increase in the breakeven point, while a 25% increase in price from $2.00 to $2.50 results in a 20% decrease in the breakeven point.

TABLE IV-J

POUNDS OF FISH REQUIRED TO BREAKEVEN AT $2.50 PER POUND BASED ON AN ANALYSIS OF ALL HANDLINE RESPONDENTS

Trips Per Year	Pounds Per Trip: Sample Mean $2.50/lb.	Estimated Distribution of Mean 50% Confidence Interval: Lower Lmt $2.50/lb.	Upper Lmt. $2.50/lb.
10	137	110	162
20	93	77	108
30	78	66	90
40	71	60	81
50	66	57	75
60	64	55	72
70	61	53	69
80	60	52	67
90	59	51	66
100	58	50	64
110	57	50	64
120	56	49	63
130	56	49	62
140	55	49	61
150	55	48	61
160	54	48	60
170	54	48	60
180	54	47	60
190	54	47	59
200	53	47	59
210	53	47	59
220	53	47	59
230	53	47	58
240	53	47	58
250	52	46	58
260	52	46	58
270	52	46	58
280	52	46	57
290	52	46	57
300	52	46	57

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

ILLUSTRATION IV-B

BREAKEVEN ANALYSIS OF HANDLINE RESPONDENTS

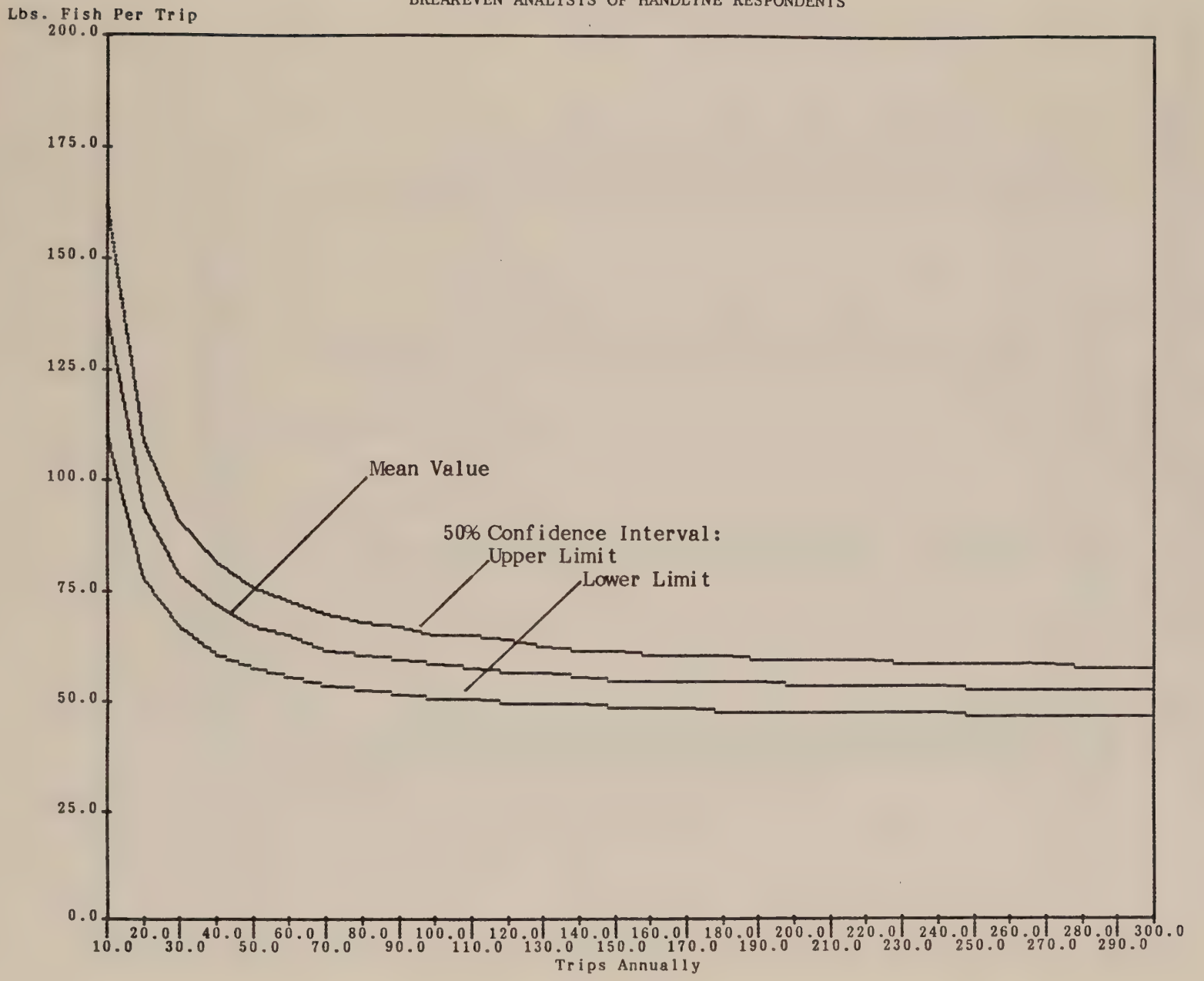


TABLE IV-K

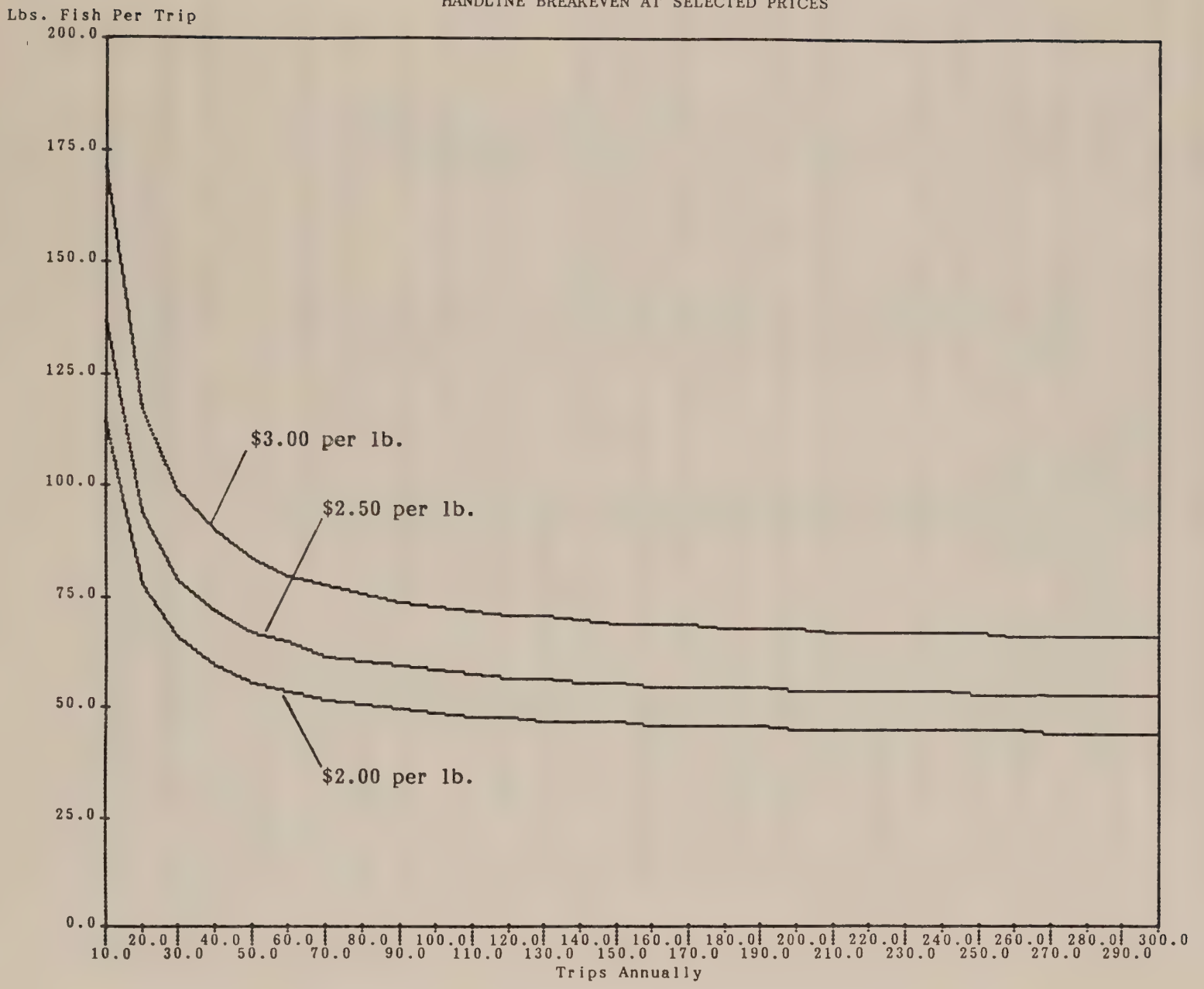
POUNDS OF FISH REQUIRED TO BREAKEVEN AT SELECTED PRICES BASED ON THE MEAN FOR ALL HANDLINE RESPONDENTS

Trips Per Year	Pounds Per Trip		
	$2.00/lb.	$2.50/lb.	$3.00/lb.
10	171	137	114
20	116	93	77
30	98	78	65
40	89	71	59
50	83	66	55
60	79	64	53
70	77	61	51
80	75	60	50
90	73	59	49
100	72	58	48
110	71	57	47
120	70	56	47
130	70	56	46
140	69	55	46
150	68	55	46
160	68	54	45
170	68	54	45
180	67	54	45
190	67	54	45
200	67	53	44
210	66	53	44
220	66	53	44
230	66	53	44
240	66	53	44
250	66	52	44
260	65	52	44
270	65	52	43
280	65	52	43
290	65	52	43
300	65	52	43

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

ILLUSTRATION IV-C

HANDLINE BREAKEVEN AT SELECTED PRICES



Return on Investment Analysis

The rate of return required by investors may be thought of as being comprised of three parts: the risk-free rate, a premium for business risk, and a premium for financial risk. The risk-free rate is the rate of return that could be earned on United States Treasury securities. The premium for business risk is attributable to the fluctuation of future operating income, and the premium for financial risk is attributable to the fluctuation of future earnings available to the proprietor, partners, or shareholders.

In the case of the handline fleet, the analysis of return on initial investment is used to estimate the volume weight of fishing activity necessary to cover an assumed 25% return on initial investment, and the total fixed, capital and variable costs assuming different periods of fishing activity ranging from 10 to 300 trips annually. Two sets of analysis were prepared and are briefly discussed below.

Table IV-L summarizes and Illustration IV-D depicts a graphic plotting of the return on initial investment analysis for the mean value of all handline responses and the estimated means at the 50% confidence interval based on an assumed 25% rate of return on initial investment and average price to the seller of $2.50 per pound. The analysis computes the average catch per trip required to achieve a 25% return for 10 to 300 trips annually. As would be expected, the catch required to achieve a 25% return on initial investment decreases at a declining rate as the

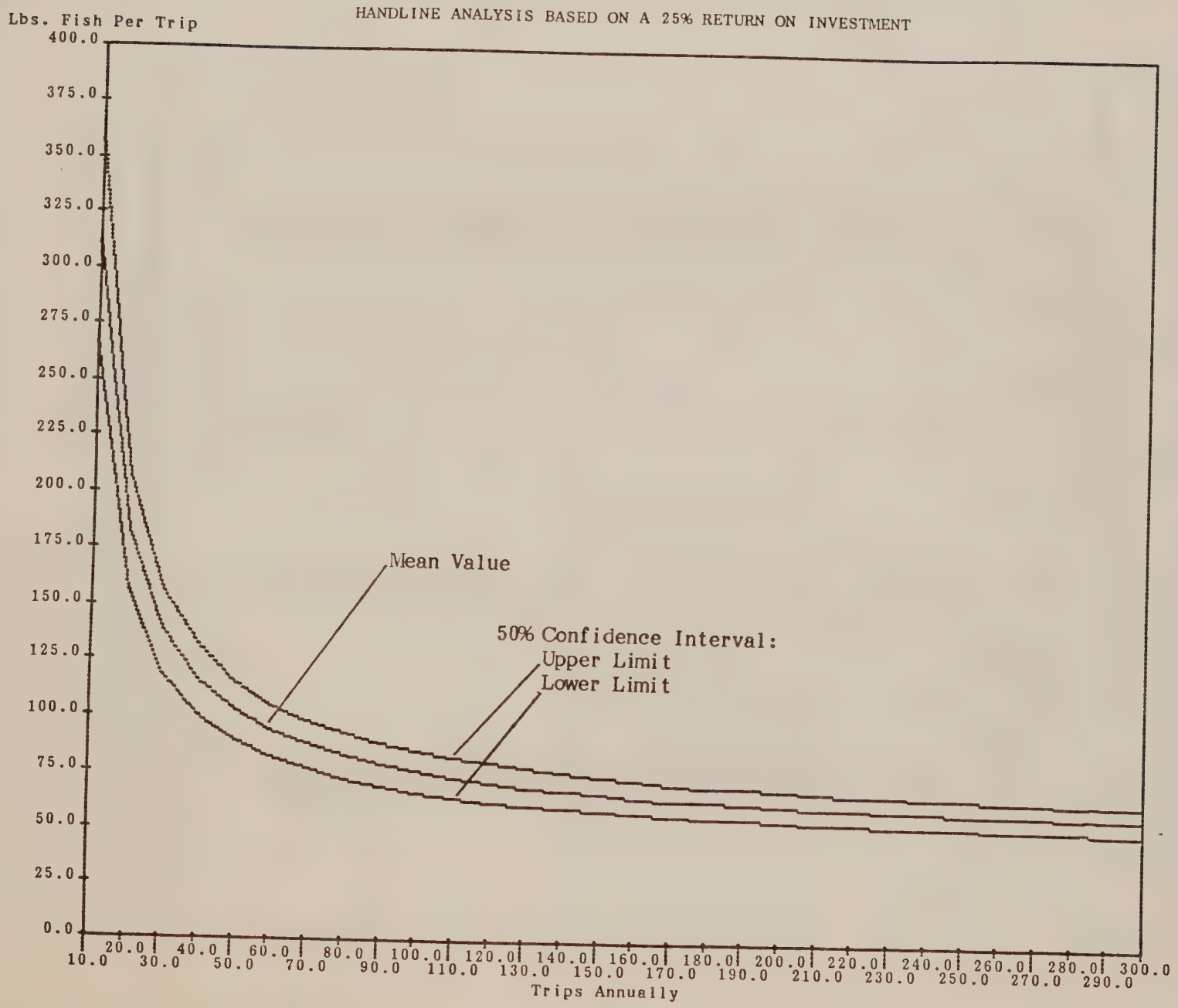
TABLE IV-L

POUNDS OF FISH REQUIRED TO ACHIEVE A 25% RETURN ON INVESTMENT BASED ON AN ANALYSIS OF ALL HANDLINE RESPONDENTS

	Pounds Per Trip		
		Estimated Distribution of Mean	
		50% Confidence Interval	
Trips Per Year	Sample Mean at 25% ROI $2.50/lb.	Lower Lmt. at 25% ROI $2.50/lb.	Upper Lmt. at 25% ROI $2.50/lb.
10	312	267	358
20	181	155	206
30	137	118	155
40	115	99	130
50	102	88	114
60	93	81	104
70	87	76	97
80	82	72	92
90	78	69	87
100	75	66	84
110	73	64	81
120	71	62	79
130	69	61	77
140	68	60	75
150	67	59	74
160	65	58	73
170	64	57	71
180	64	56	70
190	63	56	70
200	62	55	69
210	61	54	68
220	61	54	67
230	60	53	67
240	60	53	66
250	59	53	66
260	59	52	65
270	59	52	65
280	58	52	64
290	58	51	64
300	58	51	64

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

ILLUSTRATION IV-D



number of trips per year increases. Based on the mean value, after 80 trips per year a 25% return on initial investment is achieved if the average volume weight of fish caught equals or exceeds 193 pounds per trip. After 120 trips annually, the volume weight decreases to 145 pounds per trip, and after 160 trips it is 121 pounds per trip.

Table IV-M summarizes and Illustration IV-E depicts a graphic plotting of the average catch per trip required to achieve a 25% return on initial investment analysis based on the mean of all handline responses and assumes average prices to the seller of $2.00, $2.50, and $3.00 per pound of fish. As would be expected, the catch required decreases at a declining rate as the trips per year increases. Also as would be expected, there is an inverse relationship between average price per pound and the volume weight of catch required to achieve a 25% return. For example, a 20% decrease in price from $2.50 to $2.00 per pound results in a 25% increase in the volume weight required to achieve a 25% return, while a 25% increase in price from $2.00 to $2.50 results in a 20% decrease in the volume weight required.

Breakeven Relative to Return on Investment

The relationship between the volume weight required to achieve the breakeven point and the volume weight required to achieve a 25% return on investment is summarized in Table IV-N and depicted in Illustration IV-F. The analysis is based on an assumed 25% rate of return on initial investment and average price to the seller of $2.50 per pound. The difference between

TABLE IV-M

AVERAGE CATCH PER TRIP REQUIRED
TO ACHIEVE A 25% RETURN ON INVESTMENT AT SELECTED PRICES
BASED ON THE MEAN FOR ALL HANDLINE RESPONDENTS

Trips Per Year	Pounds Per Trip		
	$2.00/lb.	$2.50/lb.	$3.00/lb.
10	390	312	260
20	226	181	151
30	171	137	114
40	144	115	96
50	127	102	85
60	116	93	77
70	108	87	72
80	102	82	68
90	98	78	65
100	94	75	63
110	91	73	61
120	89	71	59
130	87	69	58
140	85	68	56
150	83	67	55
160	82	65	55
170	81	64	54
180	79	64	53
190	79	63	52
200	78	62	52
210	77	61	51
220	76	61	51
230	76	60	50
240	75	60	50
250	74	59	50
260	74	59	49
270	73	59	49
280	73	58	49
290	73	58	48
300	72	58	48

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

ILLUSTRATION IV-E

HANDLINE ANALYSIS BASED ON A 25% ROI AND AND SELECTED PRICES

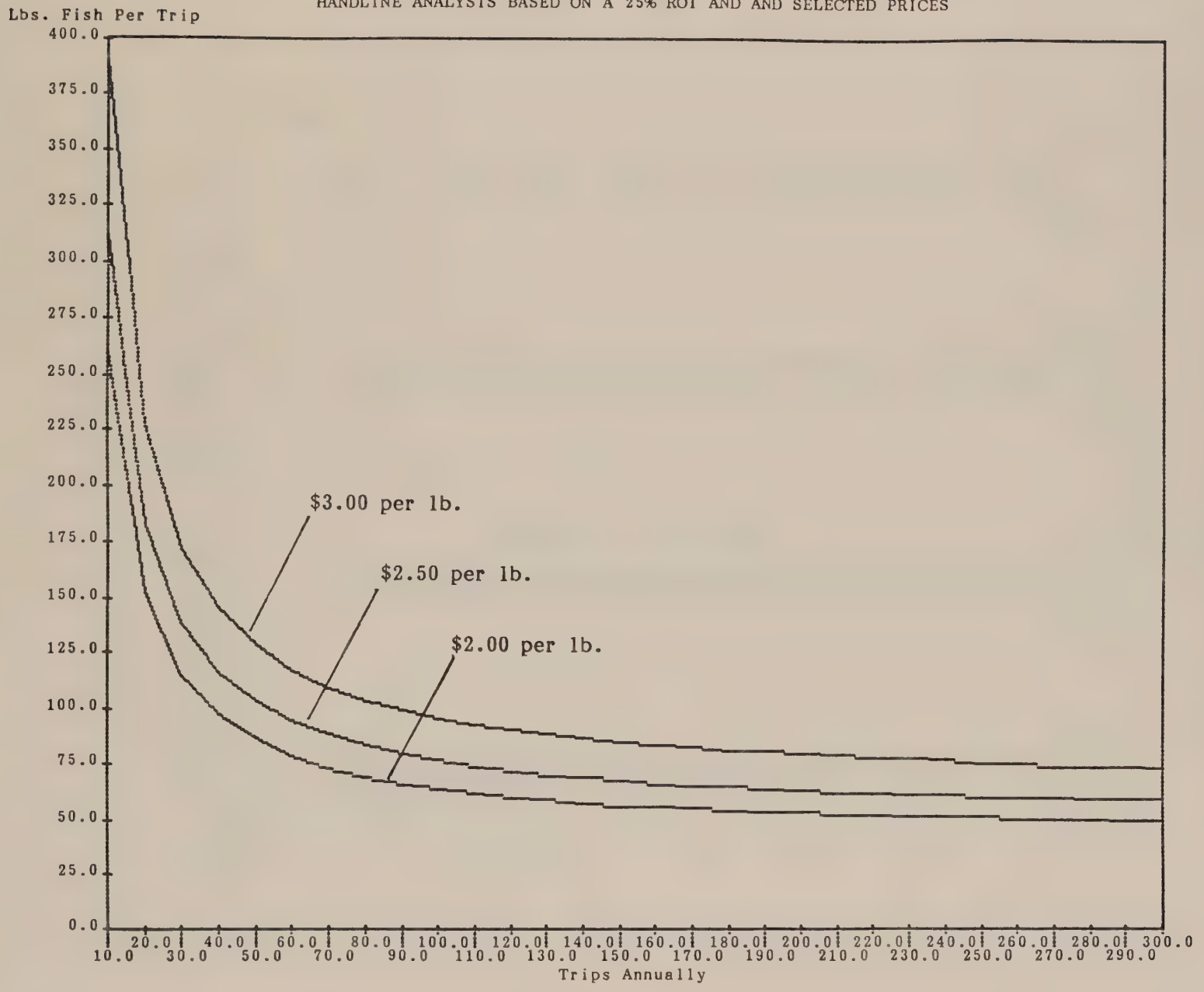


TABLE IV-N

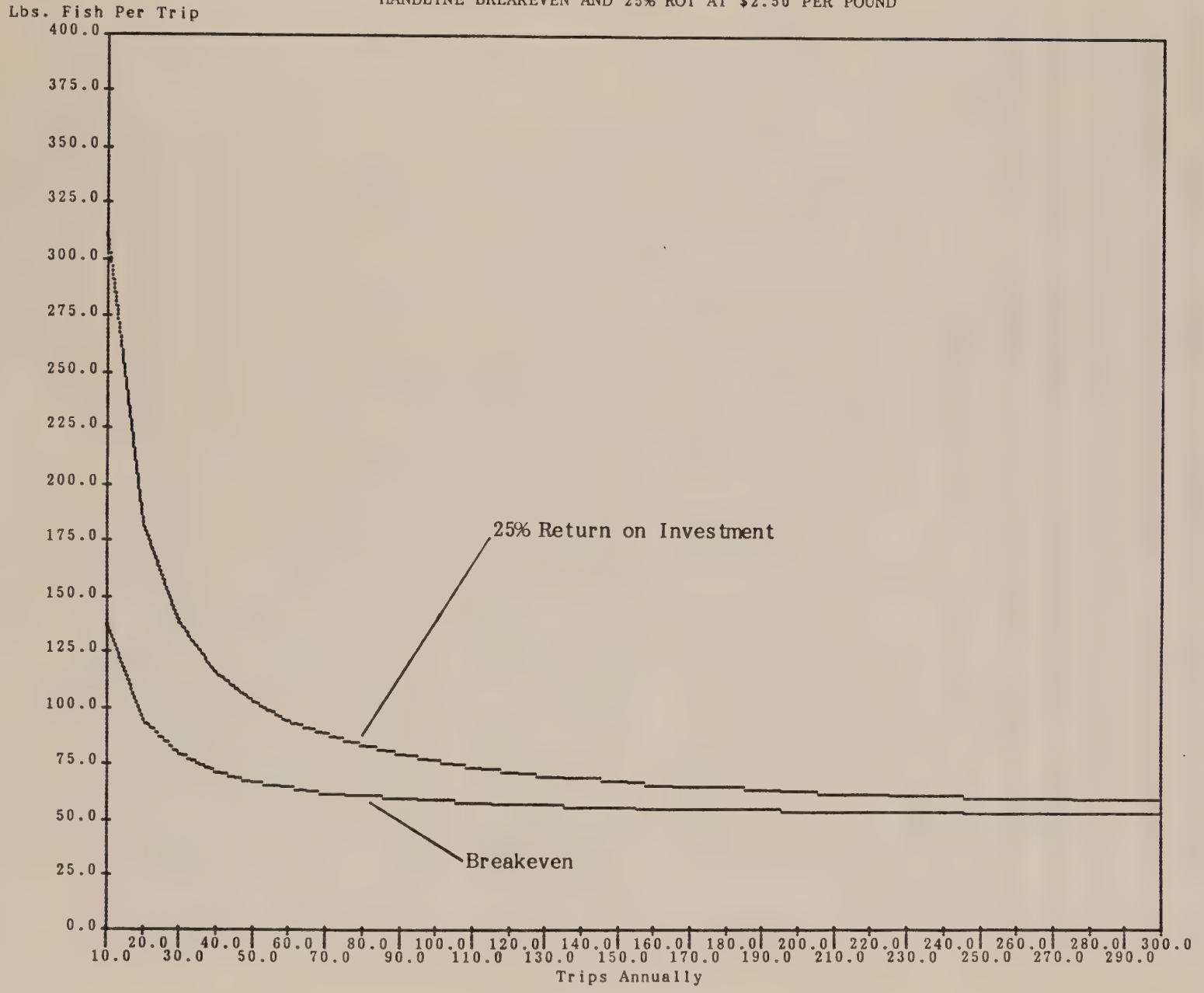
AVERAGE CATCH PER TRIP REQUIRED TO BREAKEVEN AND TO ACHIEVE A 25% RETURN ON INVESTMENT AT $2.50 PER POUND BASED ON THE MEAN FOR ALL HANDLINE RESPONDENTS

Trips Per Year	Pounds Per Trip — Volume Weight Required To: Breakeven	Achieve A 25% ROI	ROI Less Breakeven
10	137	312	176
20	93	181	88
30	78	137	59
40	71	115	44
50	66	102	35
60	64	93	29
70	61	87	25
80	60	82	22
90	59	78	20
100	58	75	18
110	57	73	16
120	56	71	15
130	56	69	14
140	55	68	13
150	55	67	12
160	54	65	11
170	54	64	10
180	54	64	10
190	54	63	9
200	53	62	9
210	53	61	8
220	53	61	8
230	53	60	8
240	53	60	7
250	52	59	7
260	52	59	7
270	52	59	7
280	52	58	6
290	52	58	6
300	52	58	6

Sources: Data from Hawaii Opinion survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

ILLUSTRATION IV-F

HANDLINE BREAKEVEN AND 25% ROI AT $2.50 PER POUND



the volume weight required to break even and that which is required to achieve a 25% return on initial investment decreases at a declining rate as the number of trips per year increases. After 60 trips per year, an additional 29 pound per trip would be required in order to increase the level of profitablity from the breakeven point to a level which achieves a 25% return on the initial capital investment. This decreases to 20 pounds per trip at 90 trips per year, and 15 pounds per trip at 120 trips per year.

V - SENSITIVITY ANALYSIS AND ASSESSMENT OF SELECTED MANAGEMENT AND DEVELOPMENT POLICIES

This chapter presents a sensitivity analysis based on the longline and handline cost and revenue analysis presented in Chapters III and IV, respectively. The chapter also assesses selected fishery management and development policies concerning maintaining sustainable yields, reducing operating costs, and increasing the per unit sales price to vessels.

SENSITIVITY ANALYSIS

The sensitivity analysis presented in Table V-A provides a basis of comparing the relative impact of changes in either the value of output; the level of effort, measured in terms of either days at sea or trips; and operating costs such as fuel and oil. The analysis indicates that:

- The catch level, or volume weight, required to break even is relatively more sensitive to decreases in the value of output than it is to increases in the value of output. A 1.00% decrease in the value of the longline output results in a 1.34% increase in the catch level required to break even, while a 1.00% increase in value results in a 0.80% decrease in the breakeven catch level.

- The catch level required to break even is relatively more sensitive to changes in the value of output then to changes in effort. While a 1.00 % decrease in the value of the longline output results in a 1.34% increase in the catch level required to break even, a 1.00% decrease in effort (expressed in terms of days at sea or trips) causes a 0.20% increase in the breakeven catch level.

- A 1.00% decrease in fuel and oil costs results in a 0.07% decrease in the longline breakeven catch level, and a 0.21% decrease in the handline breakeven catch level. The impact that decreased fuel and oil costs (or any cost factor) have on the breakeven catch level is in effect diluted by other fixed and variable expenses.

TABLE V-A

Relative Impacts of Changes in Either
Output Value, Level of Effort, or Operating Costs
On The Catch Level of Catch Required to Break Even

	Percentage Impact on Catch Level Required to Break Even	
	Longline	Handline
Change in value of output with effort and expense held constant:		
Value decreases by 1.00%	+1.34%	+1.20%
Value increases by 1.00%	-0.80%	-0.86%
Change in effort with cost and price held constant:		
Price decreases by 1.00%	+0.20%	+0.24%
Price increases by 1.00%	-0.12%	-0.14%
Decrease in fuel and oil costs with other costs, effort and price held constant:		
Price decreases by 1.00%	-0.07%	-0.21%

Source: Computations by A. Lono Lyman, Inc.

ASSESSMENT OF FISHERIES MANAGEMENT AND DEVELOPMENT POLICIES

The assessment of fisheries policies was limited by several factors. The low response rate for revenue data made it necessary to address management and development policies within the limited context of the data provided and the breakeven, return on investment, and sensitivity analysis conducted. The policy assessment does not give any consideration to either other benefits that could be derived or the costs associated with policy implementation.

Because of these factors, the analysis of fishery management and development policies was limited to a general assessment of policies related to maintaining sustainable yields, reducing operating costs, and increasing the per unit sales price to vessels. These are discussed under separate sub headings.

Policies Related to Maintaining Sustainable Yields

Attaining the breakeven catch level is critical to sustaining commercial fishing and achieving a desired return on investment is critical to expansion of commercial fishing. This suggests that policies related to maintaining sustainable yields are a very important factor in maintaining and developing both full-time commercial longline and handline fishing.

As level of effort (measured in terms of days at sea or trips) increase, the catch level separating breakeven and achieving a desired level of return on investment becomes increasingly smaller. For instance, based on a 25% return on original investment the longline data analysis in Table III-L indicates that at 100 days at sea annually, the catch level differential is 118

pounds, decreasing to 59 pounds after 200 days at sea. The handline data analysis in Table IV-N indicates that after 60 trips annually, the catch level differential is 29 pounds, decreasing to 15 pounds after 120 trips annualy.

Management practices that can be used to maintain sustainable yields include limits or bans on fishing, and permits for commercial fishing. To the extent that bottomfishing in the vicinity of the major Hawaiian islands has exceeded or is approaching the sustainable yield levels, then such measures may presently be or soon become appropriate.

Policies that maintain sustainable yields, are generally based on the desirability of both reducing financial and business risk and conservation of scarce resources. Measures which increase the cost of catching a given level of yield, such as area closures, may discriminate against cost efficient vessels, while measures which increase the potential catch may favor efficient operations.

The handline data set indicates that there are two general categories of handline fishermen: commercial and part-time recreational. Maintaining sustainable yields is of significant importance for commercial fishermen who are dependent upon fishing as their sole or as a significant source of personal income. While both commercial and recreational fishing can be affected by excessive fishing, there are several reasons to give greater consideration to commercial fishing even if it entails discriminating against recreational fishing. One reason is that recreational fishing does not have the same profit oriented objectives that commercial fishing has, and thus, by inference, can tend to

promote less efficient use of resources than commercial fishing. A second reason is that maintaining and expanding commercial fishing is more dependent upon measures that enhance profitability and reduce financial and business risk factors. Examples of such measures are management policies that limit access fisheries, or restrict the number of vessels in an area. A third factor is that the value of recreational fishing may be less dependent on catch rates compared to commercial fishing.

Policies Related to Reducing Costs

As would be expected, both the longline and handline surveys analysis indicates that improved cost parameters make possible a reduction in the catch level of fish that needs to be caught in order to either breakeven or achieve a desired return on investment. Moreover, the sensitivity analysis presented in Table V-A indicates relatively greater sensitivity to changes in price then changes in individual cost factors.

Cost reduction policies can be categorized as measures which provide in-put or operating subsidies, such as fuel tax rebates or loans at below market interest rates, and measures directed at enhancing the cost-revenue ratio, such as encouraging the use of more efficient equipment. It is concluded that policies related to reducing costs should emphasize cost-revenue efficiency rather than measures that provide an operating cost subsidy. The former is prefered since it would be more likely to result in both economic and social benefits. This is less likely to be provided by a operating cost subsidy, such as a fuel tax rebate, which may actually encourage or maintain inefficiency.

Policies Related to Increasing Per Unit Sales Prices

The sensitivity analysis in Table V-A indicates that the catch level of fish that needs to be caught in order to either breakeven or achieve a desired return on investment is relatively more sensitive to increases in the price per pound then to the changes in operating costs. The greater sensitivity to changes in price suggest that priority should be given to policies which favorably impact the per unit price obtained by the fishermen. Price supports are an example of a fishery development policy that would have a significant impact on maintaining and expanding commercial fishing.

Other policies that could favorably impact the per unit price obtained by fishermen include those related to developing or expanding markets, increasing the vessel owners' access to wholesale and retail distribution and marketing channels. Certain management policies, such as size limits, emphasize higher fillet yield and higher quality premiums and could also benefit the per unit price obtained by the fishermen.

APPENDIX[1]

FINANCIAL ANALYSIS FOR HANDLINE RESPONDENTS STRATIFIED BY SALES RESPONSE

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(1) Data from Hawaii Opinion Survey, H-83-11C.
Computations by A. Lono Lyman, Inc.

MEAN AND 50% CONFIDENCE INTERVAL
CAPITAL, FIXED AND VARIABLE EXPENSES
FOR ALL HANDLINE RESPONDENTS
WHO REPORTED SALES GREATER THEN OR EQUAL TO $10,000

	Mean	Std. Error of Mean	Est. Mean at 50.0% Conf. Lower Limit	Upper Limit	Response
Capital and Fixed Expenses:					
Boat Mortgage Paid in 1981	$5,429	2,943	$3,369	$7,489	11
Trailer Mortgage Paid in 1981	0	0	0	0	12
Other Loans Paid in 1981	265	265	80	450	12
Licenses and Fees	562	496	216	908	12
Boat Insurance	1,029	484	690	1,367	11
Tailer Insurance	27	19	14	41	11
Sub Total	$7,312		$4,369	$10,254	
Variable Expenses					
Repairs (1981):					
Engine	$823	255	645	1,001	12
Hull	129	86	69	189	12
Electronic	155	99	86	224	12
Fish Equipment	292	126	204	379	12
Sub Total	$1,399		$1,005	$1,793	
Fuel and Oil	$6,462	1,095	$5,699	$7,225	12
Fishing Gear	2,878	1,002	2,180	3,577	12
Bait	1,977	575	1,575	2,380	11
Ice	1,523	576	1,119	1,926	11
Food	1,216	310	1,000	1,432	12
Auction and Unloading Fees	3,939	1,248	3,057	4,820	9
Sub Total	$17,995		$14,630	$21,360	
Share of Fish Paid to Crew and Captain	$8,592	4,062	$5,761	$11,423	12
TOTAL VARIABLE EXPENSES	$27,986		$21,396	$34,576	
TOTAL CAPITAL, FIXED AND VARIABLE EXPENSES	$35,298		$25,765	$44,830	

TRIP ANALYSIS
FOR ALL HANDLINE RESPONDENTS
WHO REPORTED SALES GREATER THEN OR EQUAL TO $10,000

	Mean	Responses
Number of Fishing Trips Average Month	13.17	12
Duration of Trip (days)	.96	11
Duration of Trip (hours)	23.04	
Estimated Trips per Year	158.04	
Estimated Hours at Sea Annually	3,641	

VARIABLE EXPENSE ANALYSIS PER TRIP
FOR ALL HANDLINE RESPONDENTS
WHO REPORTED SALES GREATER THEN OR EQUAL TO $10,000

Variable Expenses Per Trip	Mean
Repairs:	
Engine	$5.21
Hull	.82
Electronic	.98
Fish Equipment	1.85
Sub Total	$8.85
Fuel and Oil	$40.89
Fishing Gear	18.21
Bait	12.51
Ice	9.64
Food	7.70
Auction and Unloading Fees	24.92
Sub Total	$113.86
Share of Fish Paid to Crew and Captain	$54.36
TOTAL VARIABLE EXPENSES	$177.08

CAPITAL, FIXED AND VARIABLE EXPENSES FOR ALL HANDLINE RESPONDENTS WHO REPORTED SALES LESS THEN $10,000

	Mean	Std. Error of Mean	Est. Mean at 50.0% Conf. Lower Limit	Upper Limit	Responses
Capital and Fixed Expenses:					
Boat Mortgage Paid in 1981	$716	218	568	865	40
Trailer Mortgage Paid in 1981	0	0	0	0	40
Other Loans Paid in 1981	117	77	64	170	40
Licenses and Fees	141	68	94	187	39
Boat Insurance	197	70	149	245	38
Tailer Insurance	5	3	3	7	37
Sub Total	$1,175		$878	$1,473	
Variable Expenses					
Repairs (1981):					
Engine	$1,135	510	$787	$1,484	40
Hull	292	117	212	372	40
Electronic	110	52	74	145	40
Fish Equipment	183	68	137	230	39
Sub Total	$1,721		$1,210	$2,231	
Fuel and Oil	$2,299	364	$2,051	$2,548	38
Fishing Gear	790	168	675	904	39
Bait	811	252	639	983	39
Ice	575	109	500	649	38
Food	591	140	495	687	38
Auction and Unloading Fees	1,404	934	766	2,041	32
Sub Total	$6,469		$5,125	$7,813	
Share of Fish Paid to Crew and Captain	$985	337	$754	$1,215	35
TOTAL VARIABLE EXPENSES	$9,175		$7,090	$11,259	
TOTAL CAPITAL, FIXED AND VARIABLE EXPENSES	$10,350		$7,967	$12,732	

TRIP ANALYSIS
FOR ALL HANDLINE RESPONDENTS
WHO REPORTED SALES LESS THEN $10,000

	Mean	Responses
Number of Fishing Trips Average Month	6.76	38
Duration of Trip (days)	.85	40
Duration of Trip (hours)	20.35	
Estimated Trips per Year	81.16	
Estimated Hours at Sea Annually	1,652	

VARIABLE EXPENSE PER TRIP
FOR ALL HANDLINE RESPONDENTS
WHO REPORTED SALES LESS THEN $10,000

Variable Expenses Per Trip	Mean
Repairs:	
Engine	$13.99
Hull	3.60
Electronic	1.35
Fish Equipment	2.26
Sub Total	$21.20
Fuel and Oil	$28.33
Fishing Gear	9.73
Bait	9.99
Ice	7.08
Food	7.28
Auction and Unloading Fees	17.30
Sub Total	$79.71
Share of Fish Paid to Crew and Captain	$12.13
TOTAL VARIABLE EXPENSES	$113.05

CAPITAL, FIXED AND VARIABLE EXPENSES FOR ALL HANDLINE RESPONDENTS WHO REPORTED NO SALES

	NO SALES REPORTED				
	Mean	Std. Error of Mea	Est. Mean at 50.0% Con Lower Limit	Upper Limit	Responses
Capital and Fixed Expenses:					
Boat Mortgage Paid in 1981	$849	334	621	1,076	48
Trailer Mortgage Paid in 1981	42	42	13	70	48
Other Loans Paid in 1981	450	381	190	710	48
Licenses and Fees	77	0	77	77	47
Boat Insurance	343	129	255	431	43
Tailer Insurance	0	0	0	0	42
Sub Total	$1,760		$1,156	$2,365	
Variable Expenses					
Repairs (1981):					
Engine	$960	247	$791	$1,129	47
Hull	285	121	202	367	47
Electronic	87	40	60	115	47
Fish Equipment	321	134	230	412	47
Sub Total	$1,652		$1,282	$2,023	
Fuel and Oil	$3,297	664	$2,844	$3,751	43
Fishing Gear	1,790	442	1,488	2,092	45
Bait	1,471	691	999	1,943	45
Ice	918	235	757	1,079	43
Food	991	369	739	1,243	36
Auction and Unloading Fees	468	235	308	629	37
Sub Total	$8,936		$7,134	$10,737	
Share of Fish Paid to Crew and Captain	$2,069	98	$2,002	$2,136	33
TOTAL VARIABLE EXPENSES	$12,657		$10,418	$14,896	
TOTAL CAPITAL, FIXED AND VARIABLE EXPENSES	$14,417		$11,574	$17,261	

TRIP ANALYSIS
FOR ALL HANDLINE RESPONDENTS
WHO REPORTED NO SALES

	Mean	Responses
Number of Fishing Trips Average Month	9.79	47
Duration of Trip (days)	.58	48
Duration of Trip (hours)	13.92	
Estimated Trips per Year	117.48	
Estimated Hours at Sea Annually	1,635	

VARIABLE EXPENSE PER TRIP
FOR ALL HANDLINE RESPONDENTS
WHO REPORTED NO SALES

	Mean
Repairs:	
Engine	$8.17
Hull	2.42
Electronic	.74
Fish Equipment	2.73
Sub Total	$14.06
Fuel and Oil	$28.07
Fishing Gear	15.24
Bait	12.52
Ice	7.81
Food	8.44
Auction and Unloading Fees	3.99
Sub Total	$76.06
Share of Fish Paid to Crew and Captain	$17.61
TOTAL VARIABLE EXPENSES	$107.74

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NATIONAL MARINE FISHERIES SERVICE

November 1984

HAWAIIAN MONK SEAL ASSOCIATION PATTERNS ON LISIANSKI ISLAND: 1982 PILOT STUDY RESULTS

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INTRODUCTION

This report describes findings of a pilot study on the intraspecific association patterns of the endangered Hawaiian monk seal, Monachus schauinslandi, conducted on Lisianski Island, Northwestern Hawaiian Islands (NWHI) in 1982 by the Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA. An understanding of the monk seal's association patterns is important because adult males outnumber adult females on some islands in the NWHI, and adult males have been observed to harass, injure, and kill adult females and immature seals of both sexes. This adult male behavior may significantly affect survival of females and thus further increase the imbalance between the sexes.

METHODS

Study Area

Lisianski Island (lat. 26°02'N, long. 174°00'W) is located in the NWHI approximately 905 nmi from Oahu. Its nearest neighbors are Laysan Island, 116 nmi to the southeast, and Pearl and Hermes Reef, 130 nmi to the northwest.

Lisianski Island is a coral-sand island of approximately 450 acres. The interior is covered with low vegetation and a narrow beach extends almost entirely around the 3.2-mile shoreline which is broken by coral ledges along the southeastern side and a broader expanse of beach on the southern tip of the island. Clapp and Wirtz (1975) give information on the natural history of Lisianski Island.

Subjects

Lisianski Island has a discrete, almost closed resident monk seal population (Stone 1984). In 1982 each individual in the entire population was identified by natural markings and scar patterns and by artificial bleach marks on the pelage. The population totaled 242 individuals: 27 pups of the year and 215 older monk seals. Adult males outnumbered adult females by a ratio of 2.5:1. The sex ratio was less skewed in the immature age classes but males outnumbered females in all age classes.

Data Recording

Field data were collected from 21 April to 12 September 1982 during censuses and patrols. Data were collected concurrently with other monk seal studies being conducted by a two to six person Honolulu Laboratory field camp. Censuses were conducted every 2 days by two to three observers. Censuses began at 1300 Hawaii standard time and lasted approximately 2 h each. Census procedure is described in detail by Stone (1984). Starting 11 July, patrols were conducted in addition to censuses. On census days an evening patrol was conducted and on noncensus days

morning and evening patrols were conducted. Morning and evening patrols began at 0900 and 1600, respectively. Patrols were conducted by two observers and also lasted approximately 2 h each. Patrols followed census procedure, except that only adult male seals and their "associated" animals were recorded. Census and patrol routes were rotated among observers to reduce observer bias.

In addition to data collected during censuses and patrols, incidental association data were collected when one or more of the "associated" animals could be positively identified. Association data collection was optional and collection effort varied among observers.

Two major types of association data were obtained:

1. Data on haul-out distances between individuals were recorded as the observer came abreast of the subjects. The age, sex, and identity of the individuals were recorded and distance between seals was scored into one of three categories: a) $\leq$1 m, b) >1 m and $\leq$5 m, or c) >5 m.

2. Data on behavioral interactions between individuals were obtained by focal animal and focal group observations (Altman 1973). Interactions that occurred within 30 m of the observer were recorded as bouts (sequences of interactions between individuals). The age, sex, and identity of the participants as well as the nature of the behavior exhibited were recorded.

RESULTS

Haul-Out Distances

Association incidents in which the seals were hauled out $\leq$5 m from each other totaled 1,142 and 144 behavioral bouts were recorded. Adult females spent more of their time ashore accompanied by adult males than did any other age or sex group ($P<0.05$). Adult females were observed within 1 m of an adult male on an average of 31.8% of their census sightings. The average proportion of census sightings in which other age and sex classes were within 1 m of an adult male was 7.4% for immature females, 3.8% for immature males, 0.5% for female weaned pups, and 0.9% for male weaned pups (Fig. 1).

Individual males differed in their spatial association patterns. More males were observed to associate with adult females than were observed to associate with immature seals (Fig. 2). Forty-two of the 101 adult males in the Lisianski population were seen within 1 m of an adult female on >10% of their census sightings, whereas only 6 were observed within 1 m of an immature seal on >10% of their census sightings. Thirty-one of the adult males were never seen within 1 m of an adult female on census, in contrast to 60 which were never seen within 1 m of an immature seal.

Behavioral Interactions

Nearly all agonistic interactions involved two adult male contestants ($P<0.05$), and 97% of all bouts involved two adult males, whereas agonistic interactions between adult females were not observed. The overall rate of adult male-male interactions decreased from 3.4 bouts/census in April to zero in September (Fig. 3).

A higher proportion of adult male-male agonistic bouts occurred when adult males were within 5 m of an adult female than when adult males were within 5 m of an immature seal ($P<0.05$) or when adult males were farther than 5 m from an adult female or immature seal ($P<0.05$). There was no difference in the proportion of bouts that occurred between adult males when they were within 5 m of subadult males, subadult females, juvenile males or juvenile females ($P>0.05$) (Fig. 4). The agonistic pattern changed seasonally. In April there was no difference ($P>0.05$) between the proportion of bouts that occurred when adult males were within 5 m of an adult female, an immature seal, or neither. However, from May through August, the proportion of adult male-male bouts which occurred when an adult female was within 5 m of the contestants was higher ($P<0.05$) (Fig. 5).

The average number of bouts observed per individual was lowest for those males that were never observed within 1 m of an adult female on census. The average number of bouts per individual increased with increased percent of census sightings observed with adult females, until it was highest for those males that were observed within 1 m of an adult female on 25-30% of their census sightings. However, as percent of census sightings observed with adult females increased above 30%, bouts decreased; males with the highest percent of census sightings within 1 m of an adult female (45-50%) had a lower average number of bouts than all other groups except males that were never observed within 1 m of an adult female (Fig. 6).

DISCUSSION

Adult males preferentially haul out next to and compete over adult females, and the rate of aggressive interaction is highest in the spring and early summer when the majority of adult females come into estrus.

Individual adult males differ in their spatial association patterns with adult females and immature seals, and also differ in their number of male-male bouts. The relationship between individual adult male spatial association patterns with adult females and the number of male-male aggressive interactions observed per individual indicates a possible dominance hierarchy among the adult male monk seals. No advantage is gained by challenging a contestant unless there is a good chance of victory (Maynard-Smith and Price 1973). Therefore, given a dominance heirarchy, highly dominant adult males will not be challenged in their access to adult females whereas less dominant individuals will experience a high number of challenges while in the immediate vicinity of an adult female.

An understanding of the adult male monk seal intraspecific association pattern is important because adult males have been observed to harass, injure, and kill adult female and immature seals, both acting alone or in groups during mass mobbings (instances when adult males collectively act aggressively towards other seals) (Johnson and Johnson 1981; Alcorn and Buelna[1]; Delong et al.[2]; Johanos and Kam[3]). Mobbings have immediately preceded the death or disappearance of several adult and subadult females, and may well increase the imbalance between the sexes seen at some islands in the NWHI.

Further study is needed to determine:

1. Whether there is a relationship between the occurrence of mobbing behavior and observed differences in association patterns between individuals.

2. Whether the behavior of harassing and mobbing adult females or immature seals is general or confined to a small number of rogue individuals in the adult male population.

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LIST OF FIGURES

1. Percent census sightings by age and sex class that individuals were observed within 1 m of an adult male monk seal, Lisianski Island 1982.

2. Number of individual adult males by the percent of census sightings within 1 m of (A) an adult female monk seal and (B) an immature monk seal, Lisianski Island 1982.

3. Average number of adult male-male agonistic bouts observed per census by month, Lisianski Island 1982. Sample size is noted in parentheses.

4. Percent of all adult male-male agonistic bouts observed when the contestants were within 5 m of other individuals by the age and sex class of these other individuals, Lisianski Island 1982. AF = adult female, AM = adult male, SF = subadult female, SM = subadult male, JF = juvenile female, JM = juvenile male, JU = juvenile sex uknown, PF = weaned pup female, PM = weaned pup male, UU = no other individual within 5 m of the contestants.

5. Percent of all observed adult male-male agonistic bouts by month, when the contestants were within 5 m of (A) an adult female monk seal, (B) an immature monk seal, and (C) no other monk seal, Lisianski Island 1982. Sample size is noted in parentheses.

6. Average number of agonistic bouts observed per individual adult male by average percent of census sightings these individuals were observed within 1 m of an adult female monk seal, Lisianski Island 1982.

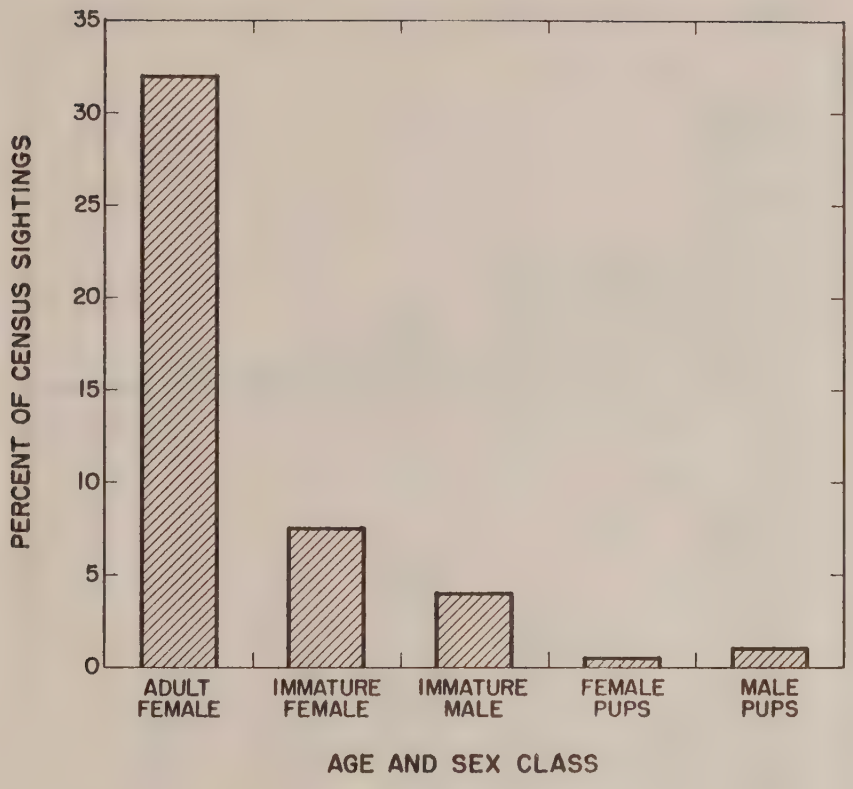

Figure 1.--Percent census sightings by age and sex class that individuals were observed within 1 m of an adult male monk seal, Lisianski Island 1982.

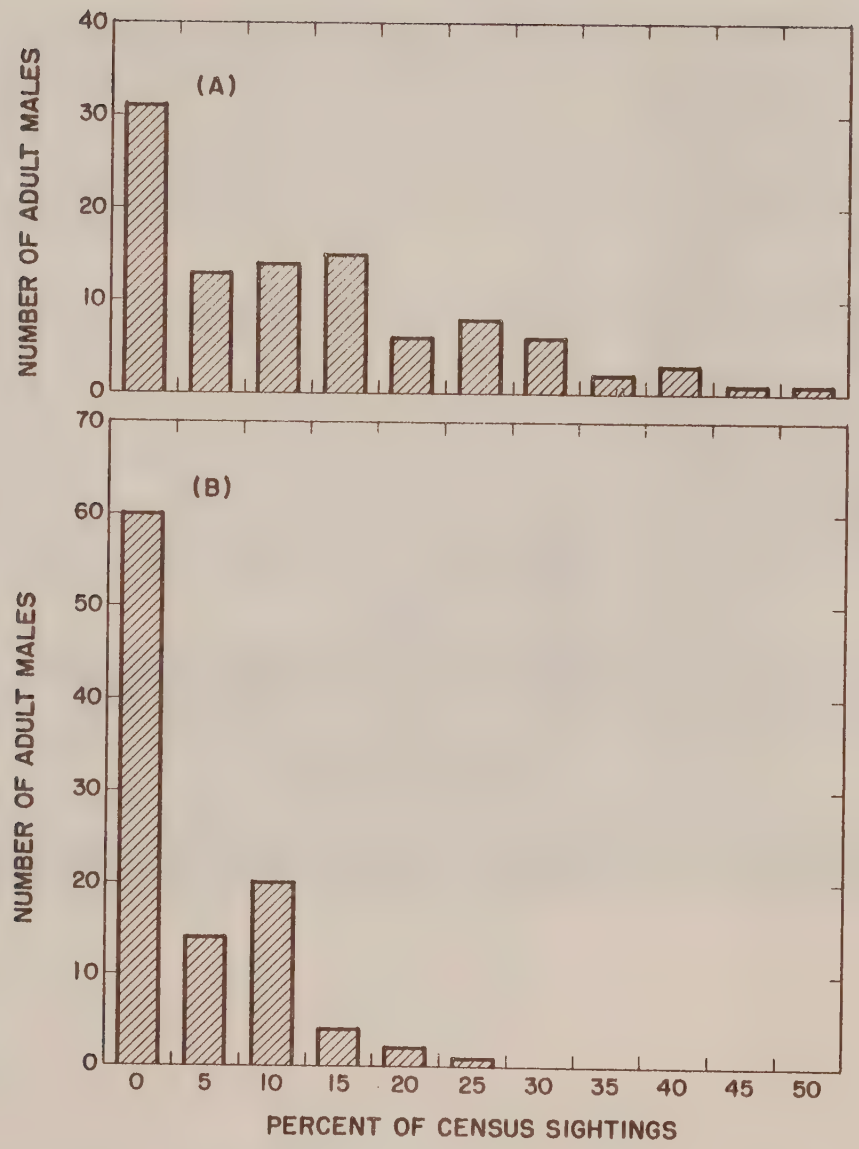

Figure 2.--Number of individual adult males by the percent of census sightings within 1 m of (A) an adult female monk seal and (B) an immature monk seal, Lisianski Island 1982.

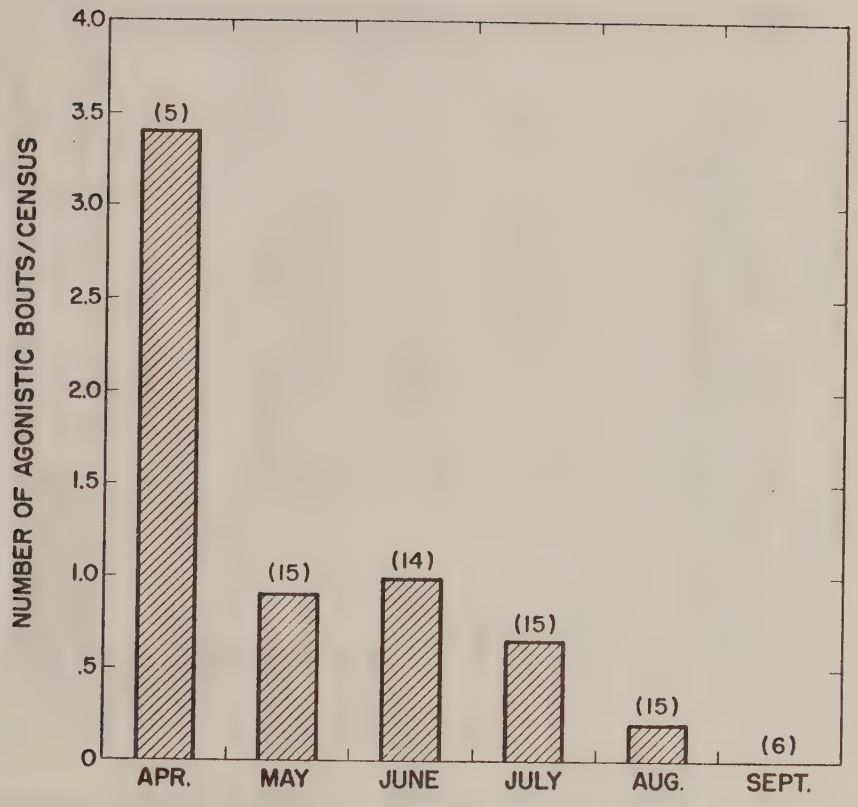

Figure 3.--Average number of adult male-male agonistic bouts observed per census by month, Lisianski Island 1982. Sample size is noted in parentheses.

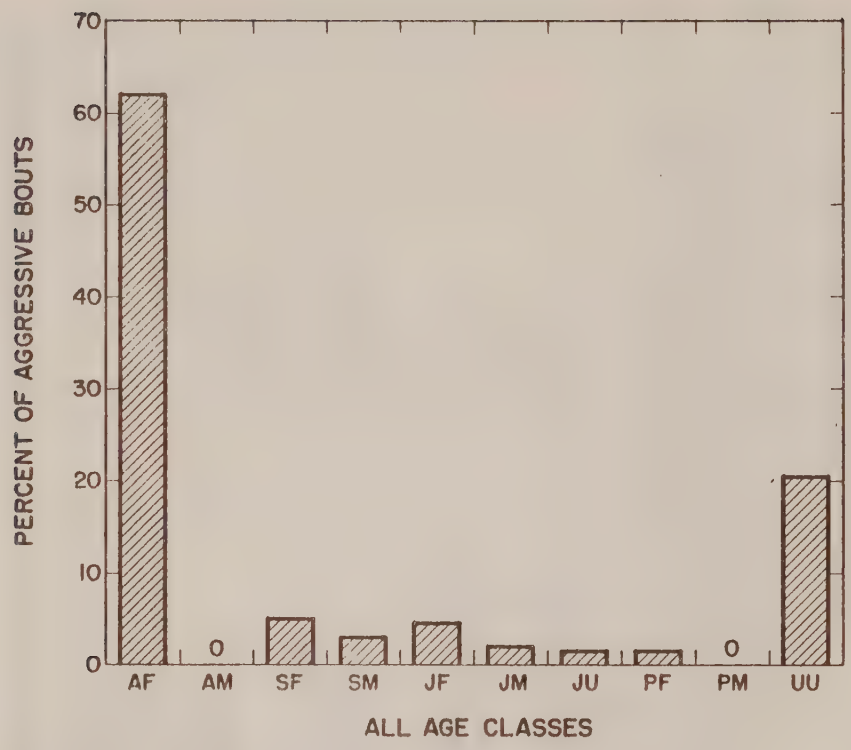

Figure 4.--Percent of all adult male-male agonistic bouts observed when the contestants were within 5 m of other individuals by the age and sex class of these other individuals, Lisianski Island 1982. AF = adult female, AM = adult male, SF = subadult female, SM = subadult male, JF = juvenile female, JM = juvenile male, JU = juvenile sex uknown, PF = weaned pup female, PM = weaned pup male, UU = no other individual within 5 m of the contestants.

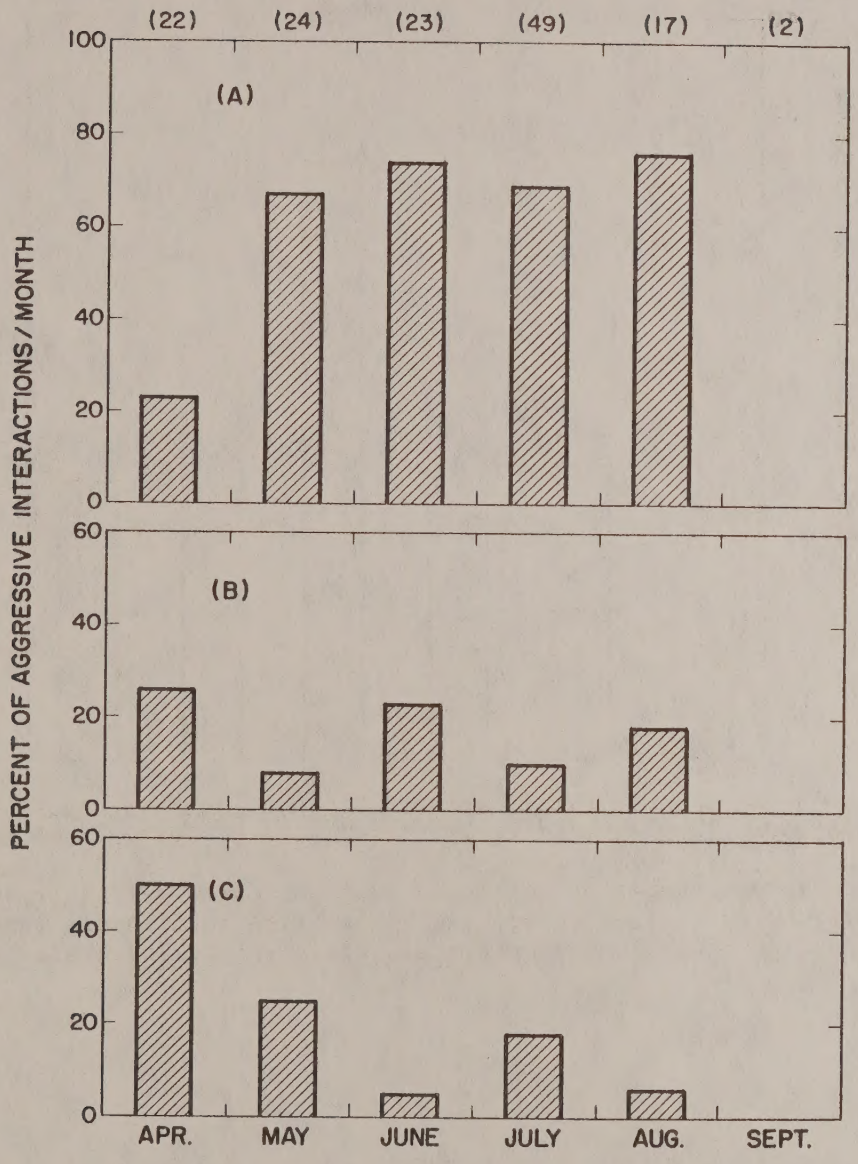

Figure 5.--Percent of all observed adult male-male agonistic bouts by month, when the contestants were within 5 m of (A) an adult female monk seal, (B) an immature monk seal, and (C) no other monk seal, Lisianski Island 1982. Sample size is noted in parentheses.

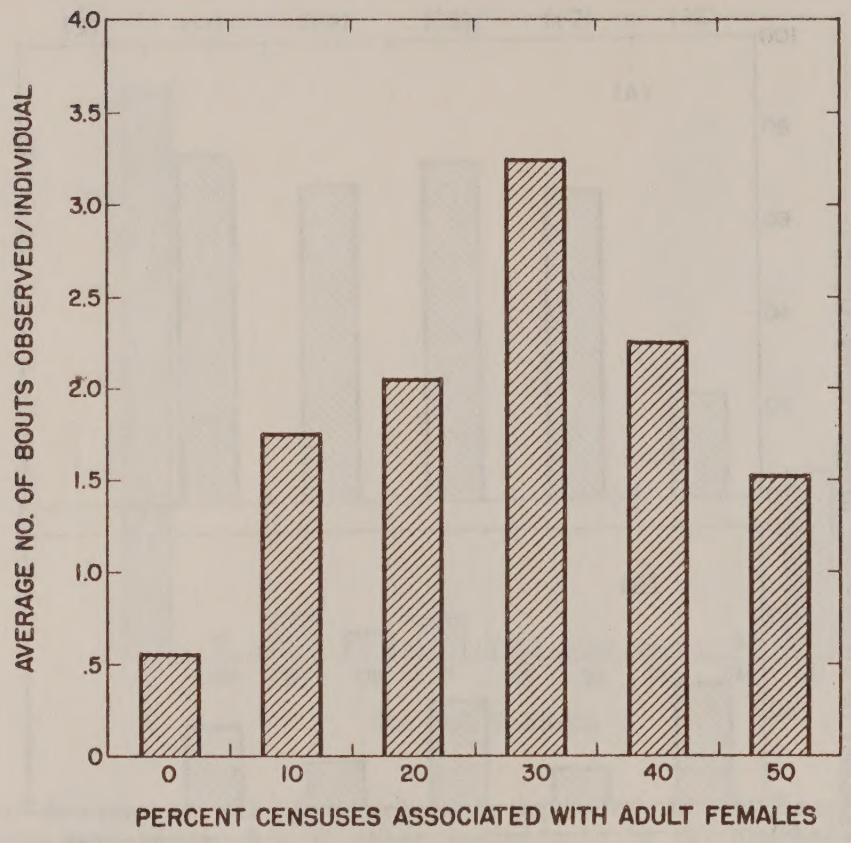

Figure 6.--Average number of agonistic bouts observed per individual adult male by average percent of census sightings these individuals were observed within 1 m of an adult female monk seal, Lisianski Island 1982.